STUDIES

IN

CARDIAC PATHOLOGY

BY

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WITH 85 ORIGINAL ILLUSTRATIONS

PREFACE

THE opportunity of photographing specimens in the museums of five of the most important hospitals of Philadelphia having been afforded the author through the courtesy of the respective pathologists of those institutions,* it has seemed worth while to reproduce the same in order to secure for these interesting examples of cardiac pathology a more enduring permanence and a more widespread field of usefulness. In order to enhance the value of the exhibit considerable data bearing on the pathology of cardiac lesions have been added. No attempt has been made to publish a complete work on the pathology of the heart, the text being mainly in the form of an explanation and an elucidation of the illustrations, and but little space has been devoted to the microscopic tissue changes. The result is perhaps open to criticism as being too statistical in nature, and the same set of statistics can, as we know, only too often, be manipulated to prove opposing hypotheses. On the other hand, it cannot be denied that statistic compilation has done considerable for the advance of medical science, and there is much truth in Kant's dictum that the amount of pure science which any given study contains is in direct proportion to the quantity of mathematics it includes.

The author has endeavored to give due credit to all concerned,

not only in the matter of specimens but also in regard to the sources of information. This has added very greatly to the time consumed in the preparation of the work and it is hoped that the attempt has been sufficiently successful to do justice to the authorities quoted and to assist such readers as may be desirous of more detailed information.

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I. ACUTE ENDOCARDITIS

EXPERIMENTAL evidence indicates that for the production of an acute endocarditis two factors are necessary. First, a predisposition or preparation on the part of the endocardium, which may be produced by mechanical, chemical, or toxic action; and, second, the presence of pathogenic micro-organisms. There has been much debate as to whether toxemia alone can ever produce verrucose lesions. Di Vecchi[1] has done considerable work on this question, and believes that he has been able to produce endocarditis by the injection of bacterial toxins together with mechanically and chemically irritant substances, such as coaldust and argentic nitrate. Fulci, who has repeated the last-mentioned experiments, was unable to produce lesions which were not also found in the control animals, unless living organisms were also injected.[2] He found, however, that toxins and mechanical irritants distinctly helped in preparing the endocardium for the inflammatory process. These last findings are quite in accord with those of other capable investigators. The mere fact that we are not always able to demonstrate organisms in the valvular lesions of endocarditis is to be explained, first, by their occasional disappearance after the lesions have been produced; second, by inadequacy of our methods of investigation; and, third, by the fact that in some instances we are doubtless

[1] Arch. di Anat. Patholog. e Scienze, 1905, and Bullet. della Scienze med. di Bologna, Jan., 1908.

[2] Fulci: Beitr. z. path. Anat. u. z. allg. Path., 1908, p. 349.

dealing with the effects of as yet undiscovered organisms, such as those responsible for scarlatina, measles, chorea, etc.

We are forced to conclude, therefore, that all cases of acute verrucose and ulcerative processes on the endocardium are infectious in origin. This, of course, does not include purely sclerotic processes, which are probably brought about in a similar manner to arteriosclerosis elsewhere.

Recent advances in bacteriology have tended to simplify greatly the subject of infective endocarditis. Much more accurate results are obtained by means of intra-vitam blood-cultures than by cultures from the heart's blood at autopsy, in which there is always a tendency for terminal infection to play a rôle. This fact probably explains the complex and hardly identifiable microorganisms described by some early observers.

FIG. 1.—ACUTE ULCERATIVE MITRAL ENDOCARDITIS.

Female, white, aged forty years. (Pennsylvania Hospital. Autopsy 408. Pathologist: Dr. Longcope. Physician: Dr. M. J. Lewis.)

CLINICAL HISTORY: Denies previous diseases. Well until two weeks ago, since which time she has had pain in the left side and a harassing nocturnal cough, without expectoration. Night-sweats, dyspnea, and edema of the legs, also slight palpitation, were present.

PHYSICAL EXAMINATION: A loud vibratory systolic murmur is heard over the body of the heart, which is transmitted to the left scapula, and can be heard over the whole chest and abdomen. A soft systolic murmur is noted at the aortic area.

PATHOLOGIC DIAGNOSIS: *Acute ulcerative mitral endocarditis.* Thrombosis of a small branch of the pulmonary artery. Acute bronchopneumonia. Anemic infarction of the spleen and kidneys.

HEART: The heart weighs 410 grams. The vessels are injected and a few punctate hemorrhages are noted below the serous surface. The cavities contain postmortem clots. The right ventricle is somewhat dilated. The endocardium is thickened. *The mitral valve is the seat of a most extensive vegetative growth, situated above the junction of the anterior and posterior leaflets. Beneath it the valve is extensively ulcerated, and several chordæ tendineæ swing loose, being attached only to the vegetations. The vegetative mass is lobulated and nearly the size of a walnut; it extends to the auricular surface for 2.5 to 3 cm., and when the heart is held in the upright position, practically fills the auriculo-ventricular orifice. The vegetations are delicate, gray, soft, friable, and lobulated. Numerous soft, gray, pinhead-size vegetations cover the posterior leaflet and part of the auricular wall.* The aortic valves are thickened and somewhat calcified at the bases, but show neither retraction nor vegetation. The muscle is soft, brownish-gray, and fragments easily. The coronary arteries show an extensive grade of sclerosis, and in places are converted into rigid tubes. The aorta immediately above the valves, shows a diffuse dilatation, measuring 9 cm. in circumference. Its wall is fairly smooth.

MICROSCOPIC DIAGNOSIS: The pericardium is normal. *Muscle-fibers* are rather granular and have partially lost their cross-striæ. Between them some connective-tissue formation is noted. The *valvular vegetations* showed diplococci, slightly lanceolate in form, Gram-positive. Cultures showed numerous very small pin-point colonies, barely visible to the naked eye.

Fig. 1.

Classification.—A satisfactory classification of acute infectious endocarditis is at present impossible. No distinctions can be made which will always hold good. A division into simple and infective is fallacious, since probably all cases are infectious in origin. Benign and malignant is equally unsatisfactory, inasmuch as there are no "benign" cases, the endocardial changes instituted being always sooner or later serious. A bacteriologic classification is also objectionable, because although certain micro-organisms tend on the whole to produce certain types of changes, yet there are so many exceptions and uncertainties as to make this basis infeasible. Finally, a classification into simple, ulcerative, verrucose, etc., based upon anatomic appearances is useless, since these are not radical differences, but largely accidental characteristics, which merge more or less insensibly into each other. On the other hand, there are clinical types of the disease which are quite distinct from each other, in the onset, course, and termination, so that some sort of differentiation must be attempted. Osler

FIG. 2.—MALIGNANT ENDOCARDITIS, AORTIC AND MITRAL.

J. M., male, white, aged thirty-three years. (Philadelphia Hospital. Autopsy: Vol. xxii, p. 32. Physician: Dr. J. Tyson. Pathologist: Dr. Foster.)

CLINICAL NOTES: Laborer, hard worker. Alcohol to excess. Tobacco moderate; denies syphilis. Malaria in Philippines. Rheumatism three years ago. Epigastric pain, cough, hemoptysis, vertigo, diplopia. Corrigan pulse; radial sclerosis. Heart enlarged to right and left. First sound only fair. Pulmonic second accentuated. Apex-beat: sixth interspace, 1 in. outside midclavicular line. Systolic murmur at third left costal cartilage.

PATHOLOGIC DIAGNOSIS: *Malignant endocarditis—aortic and mitral;* aortic insufficiency; parenchymatous degeneration of heart; hemorrhagic infarcts of kidney, spleen; fatty degeneration of liver; chronic parenchymatous nephritis, with beginning interstitial changes; healed bilateral pulmonary tuberculosis, etc.

PERICARDIUM: Contains 60 c.c. of blood-tinged fluid. Serous surface smooth and glistening.

HEART: Weighs 470 grams; is large and flabby; pale in color. Absence of epicardial fat. Vessels prominent and engorged. *Aortic valves incompetent to water test.* Heart muscle soft, brownish-red, and granular. Papillary muscles pale. Aortic orifice, 8; mitral, 11; tricuspid, 14; pulmonary, 7 cm. in circumference.

On the anterior and left posterior aortic leaflets there are rough, reddish-yellow vegetations about 1 cm. in diameter. On the ventricular surface of the mitral leaflet there is a large, irregular, cauliflower-like mass, 2 x 2 x 1.5 cm. Inflammatory changes incident to this massive vegetation have occurred on the auricular surface of this leaflet, and consist of three circumscribed areas of roughening covered with plastic lymph. The other valves are uninvolved. The base of the aorta shows beginning atheromatous change about the coronary orifices.

FIG. 2.

has suggested the following division: (1) malignant; (2) simple acute; (3) chronic.

The virulence of the causative organism is often more important than the species. Organisms of low virulence may produce severe subacute attacks without the production of any bactericidal reaction on the part of the host. The main difference between these types is in the amount of endocardial inflammation and tissue necrosis. In malignant endocarditis emboli are more frequent and more septic, right-sided involvement more common, and micro-organisms are oftener found in the blood, in the emboli, and on the valves. These cases are nearly always secondary and generally fatal. Infants and children seem to be almost exempt from this form of the disease.[1]

Morbid Anatomy.—The earliest visible manifestation of acute endocarditis consists in an opaque or slightly rough area upon the valves or endocardium. If the process continues, bead-like, nodular elevations appear which eventually develop into distinct verrucæ. The amount of fibrin which exudes is very variable, and upon this factor the appearance of the inflammatory products largely depends. Where free outpouring occurs, large fleshy vegetations are seen. When very little occurs, necrotic changes in the endocardium producing various degrees of ulceration may predominate in the picture. Even small vegetations entail destruction of the endocardium. Larger growths have a deeper origin and cause relatively greater destruction of tissue. A combination of fungating and ulcerating lesions is the rule in the severe forms. The latter may produce valvular perforation, and even destruction of the underlying myocardium. (See Fig. 6.) Occasionally, necrotic areas without ulceration or foci of suppuration occur. The vegetations vary greatly in appearance; at times soft, friable, gelatinous, white, reddish or yellow masses with adhering blood-clots; again, the well-known cauliflower growths are seen. In cases in which friction has been

[1] Sicard (32 cases, Presbyterian Hospital, New York): Amer. Jour. Med. Sci., Nov., 1904.

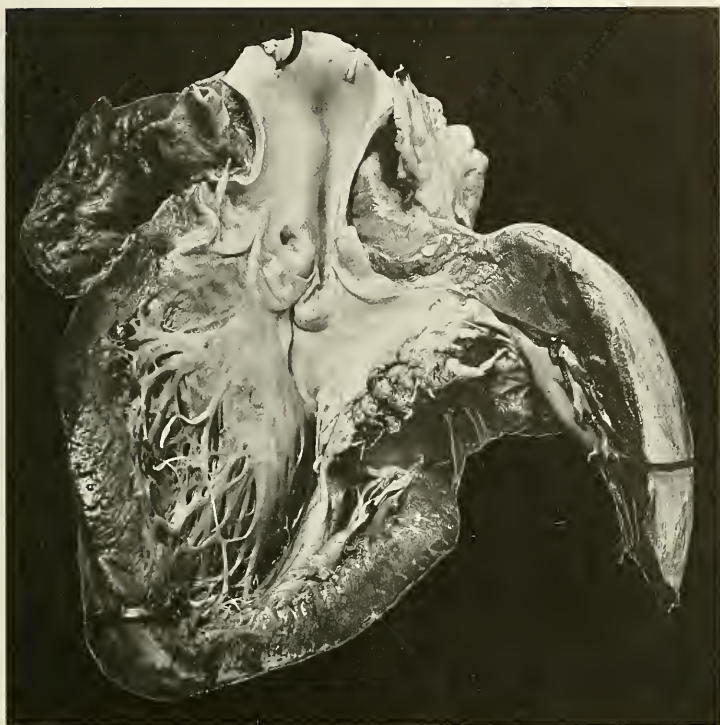Fig. 3.—Acute Infective Mitral and Mural Endocarditis.

The mitral valve is covered with large vegetations. Several of the chordæ tendineæ have been destroyed by ulceration, only short unattached stumps remaining. Vegetations are also seen on the mural endocardium. (Specimen from the Pennsylvania Hospital.)

marked, long pendulous thrombi may occur. (See Fig. 12.) Osler states that fibrous changes, and even calcification, may occur even in acute cases. In such cases the condition might be confused with the necrotic changes seen in arteriosclerosis without micro-organismal infection.[1]

Thrombosis in the auricular appendages, especially if associated with necrosis, may also at times simulate mycotic endocarditis. Severe cases may perforate septum or heart itself.

Simple endocarditis occurs especially at the line of valvular contact; the endocardium becomes swollen, translucent, and somewhat beaded. As the distended endothelial cells are detached the blood-plaques agglutinate into small masses, which in time, by the addition of leukocytes, develop into good-sized warty growths.

In severe cases the chordæ tendineæ and the papillary muscles are involved in infiltration and inflammation. The mural endocardium is less often involved than that of the valves, owing to lessened functional activity.

Malignant endocarditis may be primary or secondary; the right-sided valves are attacked oftener than in the simple variety. The vegetations tend to be more exuberant and friable, and mural involvement is commoner. Valvular rupture (chiefly mitral and aortic) is sometimes preceded by aneurismal dilatation of the same, extending in the direction of greatest pressure. An aneurism of the mitral valve generally involves the anterior flap. (See Fig. 14.) Rupture of the valves or chordæ tendineæ, especially when the process is acute, is usually preceded by old valvular disease. Myocarditis may occur by extension of the inflammatory process.

The infarcts of malignant endocarditis perhaps so rarely lead to suppuration on account of the low virulence of the organisms to which many cases owe their existence. Embolic manifestations vary greatly in different cases. Sometimes they are very extensive,
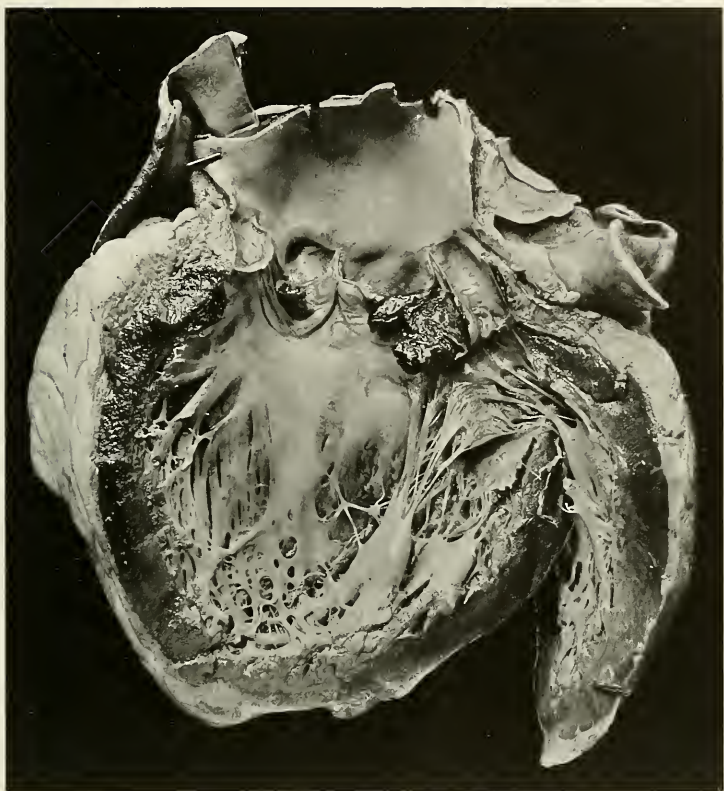
[1] Brit. Med. Jour., Mar. 7, 1885, p. 438.

FIG. 4.—ACUTE INFECTIVE ENDOCARDITIS.

Specimen showing large thrombi formed on the ulcerated areas of the aortic leaflets. Also very small verrucæ in the sinus of Valsalva, and some small mural thrombi between the columnæ carneæ of the left ventricle.

as in Hoper's case of mitral stenosis, in which both femorals, the right internal iliac, the right renal, the superior mesenteric, and the left brachial arteries were occluded by emboli.[1]

The verrucose vegetations of endocarditis, which, as Hirschfelder has pointed out, may form within a few hours after damage to a valve, are in part the result of the action of the blood-stream upon the fibrinous exudation. In long-standing cases contraction of organizing fibrin doubtless plays a part in the production of wartlike vegetations.

Predisposition.—The more frequent involvement of the left side of the heart has been explained by the fact that after birth blood-pressure is higher and oxygenation greater than on the right. The former, as the result of stress and trauma, favors the localization of micro-organisms, the latter favoring both localization and growth.[2]

In 237 cases of congenital endocarditis Rauchfuss found the lesions right-sided in 192. The relative frequency of right-sided lesions in fetal life was ascribed by Rokitansky to the effect of congenital malformations, a belief which subsequent investigation has corroborated. Yet despite the fact that this predisposition exists, the engrafting of an acute endocarditis upon a congenital lesion is not common, owing to the fact that malignant endocarditis is a disease of middle life, an age which the subjects of developmental heart lesions do not, as a rule, attain.[3] G. C. Robinson[4] has collected 17 cases of endocarditis and congenital malformation, adding two cases thereto, and omitting those in which the malformation was limited to the valves. In 11 cases there was deficiency of the interventricular septum, and in 6 of these pulmonary valvular obstruction. Fig. 76 was from one of the cases published by Robinson. Fig. 77 also illustrates the coincidence of infectious endocarditis and congenital defect.

Embolic manifestations in the lung, spleen, kidneys, etc., are much more frequent in malignant or "infective" endocarditis than in the simple type. Among 64 cases of the former, Glynn found 44 instances; among 64 of the latter, only 18.[5]

[1] Hoper: Lancet, Aug. 18, 1906.

[2] Wadsworth: Jour. Infect. Dis., 1909, p. 279.

[3] Malignant endocarditis is rare in childhood. The statistics of Steffen, Von Dusch, Hochsinger, and Weil show that 62 per cent. are of the simple variety, and involve the mitral valve. Endocarditis is rare in infants. Holt failed to find any instance in 1000 autopsies on children under three years; Steffen, in 45 cases, found only 5 in the first year of life; Hochsinger, in 53 cases, only one in the first year of life; v. Dusch, in 45 cases, 5 between eight months and three years; Sutiagin, in 108 cases, 11 in the first year of life.

[4] G. C. Robinson: Bull. Ayer Clinical Laboratory, Pennsylvania Hospital, 1905.

[5] Lancet, April 18, 1903, p. 1073.

FIG. 5.—SUBACUTE INFECTIVE ENDOCARDITIS.

Showing large thrombotic masses almost completely occluding the aortic orifice. There is marked left ventricular hypertrophy, and sclerotic patches are seen on the aorta above the sinus of Valsalva.

Pathogenesis.—Any infectious disease may be accompanied
or followed by an endocarditis, which may be homologous, heter-
ologous, or due to a mixed infection. A predisposition to it is
to be found in the minute endothelial lesions, which are naturally
commonest where pressure or friction is greatest—on the mitral
valve. When this valve is insufficient, the right heart may be
more likely to develop acute endocarditis, as in a case described
by Marini.[1] The youthful endocardium is much more suscep-
tible to infection than that of advanced years, as Church's statistics
of 700 cases show:[2]

1 to 10 years	80 per cent.	
10 " 20 "	69	"
20 " 30 "	62	"
30 " 40 "	30	"
40 " 50 "	21	"

Further corroboration is to be found in the well-known fact that
in the rheumatic fever of childhood the heart rarely escapes involve-
ment, whereas in adults this is by no means so unusual an occur-
rence.

Dunn[3] in 300 cases of rheumatic arthritis at the Children's Hospital in
Boston found evidences of endocarditis in 140, and of pericarditis in 58. Two
hundred and eighty-one at some time in the attack showed evidences of endo-
carditis, so that only 19 in all escaped entirely. Mitral insufficiency was noted
70 times, a double mitral lesion 56 times. The 140 cases were admitted as
"endocarditis," there being other evidences of disease at that time. Thus 60
per cent. of the cases showed distinct evidences of endocarditis at a time when
there were no arthritic manifestations.

The tendency of certain organisms to attack the endocardium is well exem-
plified by Lenhartz's results: In a study of 226 cases of general sepsis, there were
38 cases of malignant endocarditis. In 149 cases of sepsis due to the strepto-
coccus pyogenes there were but 6 cases of endocarditis. In other words, the
streptococcus is the most common cause of sepsis, in scarlatina, the puerperium,
etc.; yet, proportionately, endocarditis was much more common in the cases due
to the other organisms. On the other hand, 95 per cent. of the staphylococcus
cases showed endocarditis.[4] (His investigations revealed: staphylococcus 10,
pneumococcus 10, streptococcus 16, gonococcus 1.)

[1] Marini: Gazz. degli ospedali, 1907, No. 24.   [2] St. Bart. Hosp. Report, xxiii.

[3] Dunn: Jour. Amer. Med. Assoc., 1907, p. 493.

[4] Lenhartz, quoted by Reye: Jahrb. d. Hamburger Staatskrank. Anst., 1905, p. 224.
(The valvular involvement in these cases was as follows: Mitral, 18; aortic, 11; both, 2.
Tricuspid, 4; pulmonic, 2; aortic and pulmonic, 1.)

The researches of Prudden,[1] Rosenbach,[2] Wyssokowitch,[3] and Rosenow[4] have demonstrated the fact that endocarditis is more apt to develop on an endocardium which has been previously injured or diseased than on a normal one. Goodhart[5] found apparently antecedent valvular thickening in 61 out of 69 cases. A large number of different organisms have from time to time been described as the causative factor of endocarditis. "The colon, Friedländer, typhoid, diphtheria, influenza organisms, the meningococcus, the tubercle bacillus, the bacillus pyocyaneus, unrecognized species, others little known but described as the bacillus endocarditis griseus, the micrococcus rugatus, the micrococcus capsulatus of Weichselbaum, the bacillus pyocyaneus fetidus (Fasset), the diplococcus tenuis (Klemperer)—these and other organisms have been credited with producing the condition" (Wadsworth[6]). At present there seems to be a tendency to regard many of these diverse and little known organisms as atypical forms of well-known varieties, such as the streptococcus. The pneumococcus, the staphylococcus, the streptococcus, and the gonococcus are undoubtedly the most frequent causes of malignant endocarditis. "Bacterial species comparatively benign in other parts of the body prove serious and fatal in endocardial lesions" (Wadsworth).

Among 50 cases of pneumococcus endocarditis, 25 per cent. showed old lesions upon which the recent infection had become engrafted (Preble).

Although the difference between simple and malignant endocarditis is nearly always only one of degree, yet certain infections have a marked tendency to cause definite types. Thus rheumatic fever and chorea, so frequently the cause of simple endocarditis, rarely cause the malignant variety; whereas with pneumonia and puerperal sepsis the reverse is the case. The mere fact that

[1] Prudden: Am. Jour. Med. Sci., 1887.
[2] Rosenbach: Arch. f. exper. Path., 1878.
[3] Wyssokowitch: Virchow's Arch., 1886, p. 301.
[4] Rosenow: Jour. Infect. Dis., vi, 1909, p. 245.
[5] Goodhart: Trans. London Path. Soc., xxxiii, p. 52.
[6] Wadsworth: Med. Record, Dec. 28, 1907.

endocarditis complicates a disease is, of course, no indication that this is not due to a secondary infection with some other species of organism. For example, the pyogenic cocci are generally the cause of endocarditis in diphtheria and tuberculosis, although both the Klebs-Löffler and the tubercle bacillus have been shown, both clinically and experimentally, to possess the faculty of producing endocardial inflammation. However, we must not forget that "the organism isolated from an ulcerative case may experimentally in one case animal give rise to an ulcerative form of endocarditis, while in another animal of the same species simple endocarditis may result."[1]

Sometimes the experimental injury of valves in animals has been followed by lesions similar to those of malignant endocarditis; although not the ulcerative type, which appears to occur only when infection is also present. It is conceivable, therefore, that valvular rupture might give a similar picture in man. Practically, however, malignant endocarditis means a severe type of infection, localized either by means of the general blood-stream or the coronary arteries. Slight local injury, such as the application of nitrate of silver, is enough to determine the focus of the infection on the endocardium (Prudden). The mycotic origin of practically all cases of verrucose endocarditis is generally admitted. Articles bearing on this subject are very numerous. Thus Bartel[2] studied 23 cases and concluded that all cases of verrucose endocarditis have such an origin; the extent of the lesion varying with the duration and virulence of the infection, and with the amount of individual tissue resistance.

Rheumatic fever is by far the most prolific source of "simple" endocarditis, from 80 to 90 per cent. of this variety being due to this cause. Rheumatic fever is now universally regarded as an infection, and although the exact micro-organism which causes it has not yet been definitely determined, the majority of cases

[1] Beattie and Dickson: Special Pathology, 1909, p. 12.
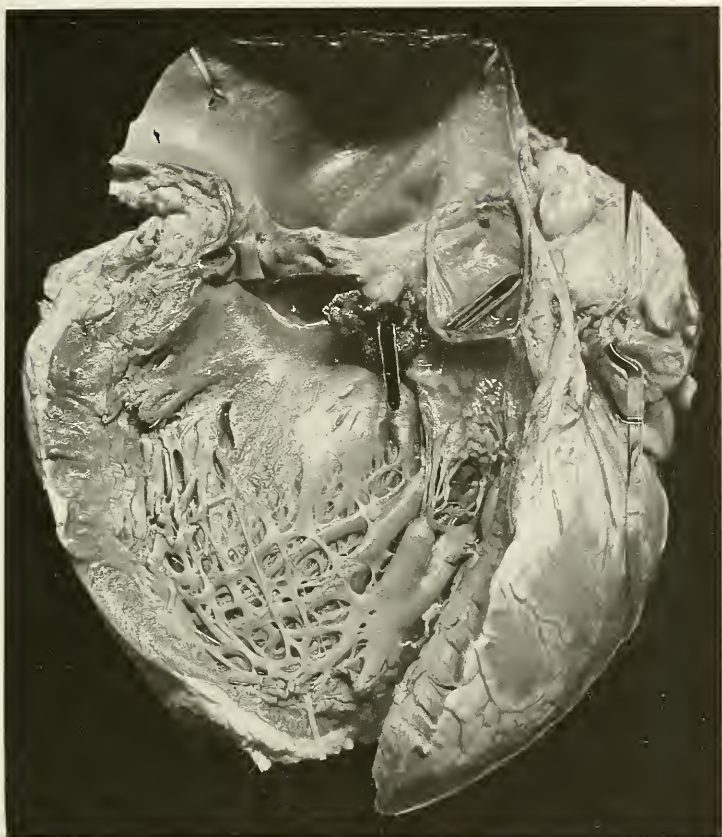[2] Bartel: Wien. klin. Woch., Oct. 10, 1901.

FIG. 6.—ACUTE INFECTIVE ENDOCARDITIS.

Showing extensive ulceration of the aortic valves. About the center of the aortic orifice a match-stick projecting from a thrombotic mass indicates the course of the perforation in the aortic leaflet. (Specimen from the Philadelphia Hospital.)

owe their origin to various organisms of the streptococcus group.
A diplococcus described by Wassermann, and later by Poynton
and Paine, Longcope, and others, seems to be responsible for a
considerable number of the cases. According to Beattie and
Dickson, the diplococcus rheumaticus, which is a common in-
habitant of the mouth and intestines, may, under certain condi-
tions of increased virulence on the part of the germ, or decreased
resistance on the part of the host, produce the infection. They
suggest that some of the cases of endocarditis occurring in rheu-
matic fever, Bright's disease, scarlatina, and chorea may thus
arise.[1]

Sibson in 325 cases of rheumatic fever found endocarditis in 130, both
endocarditis and pericarditis in 54, and the latter alone in 9. Seventy-nine per
cent. of the cases with previous endocardial lesions developed an acute infection,
whereas of those with no antecedent disease only 56 per cent. were afflicted.
Among 270 cases of rheumatic fever studied by McCrae, 85, or 32 per cent., had
undoubted organic endocardial disease—mitral, 95 per cent.; aortic, 23 per
cent.; both valves, 18 per cent. Of the 85 cases of mitral involvement, 54 were
insufficiency, 3 obstruction, and 8 a double lesion. At St. Thomas' Hospital
among 535 cases of rheumatic fever the mitral valve was involved in 97 per cent.,
the aortic in 12 per cent., the aortic alone in 3 per cent. There were apparently
no cases of malignant endocarditis in McCrae's series. He found in addition to
the above mentioned cases 78 (28 per cent.) in which organic disease was doubt-
ful; of these, 60 were discharged with murmurs of uncertain cause. In 136 cases
of rheumatic fever reported by Latham, 90 showed cardiac involvement—63
endocarditis, 7 pericarditis, 11 both, 9 doubtful cases. Among 150 cases of
infective endocarditis at St. Bartholomew's Hospital, Horder found that 72 gave
a history of acute or subacute rheumatic fever or chorea, 10 of scarlatina, 7 of
gonorrhea, 4 of typhoid fever, 4 of malaria, 2 of syphilis, 2 of influenza, 1 of
exophthalmic goiter, 1 of dysentery, 1 of pneumonia. In 53, no history of pre-
ceding disease could be obtained. Phillips in 210 cases of acute rheumatic fever
found 63 cases of undoubted endocarditis—mitral 56, aortic 13, both 11. Among
288 cases of rheumatic arthritis in Christiania there were heart complications in
33 per cent.; and of 242 cases of heart disease there was a history of rheumatic
fever in 46.5 per cent., of syphilis in 9.2 per cent., influenza in 2.5 per cent. Of
the chorea cases 31 per cent. showed cardiac lesions.[2] Among 30,000 patients,
Litten found 400 cases of endocarditis. In 35 per cent. of these the cardiac

[1] Details regarding the bacteriology may be found in Bulloch's article, "Rheumatic Fever,"
vol. ii, part 9, of the new edition of Allbutt and Rolleston's System of Medicine, 1906, vol. ii,
part i, p. 594.

[2] Thiis: Norsk Mag. f. Laegevedenskaben, Oct., 1909, lxx.

lesion was certainly due to rheumatic fever. In 30 per cent. other definite causes could be assigned, and in the remaining 30 per cent. no etiologic factor was demonstrable.[1] Forssner[2] found that 45 out of 74 cases of acquired heart disease in children, and 32 among 60 in adults, resulted from rheumatic fever. Romberg in 670 cases of valvular disease at the Leipzig clinic found that 58.9 per cent. were rheumatic in origin. Among 258 cases of acute endocarditis in children Perroud[3] found it associated with different infectious processes as follows: rheumatic fever, 150; chorea, 39; tuberculosis, 15; scarlatina, 12; pneumonia, 7; measles, 7; diphtheria, 7; typhoid fever, 4; dysentery, 3; erythema nodosum, 2; undetermined, 12.

In a study of 1,369 clinical reports of *scarlatina* cases, Rochely found no acute endocarditis, nor did Reimer among 48 autopsies. The endocarditis of scarlatina and *variola* is said to be generally of the simple variety. In 550 cases of scarlatina, Beatty[4] found 7 cases of endocarditis. It has also been reported following *vaccination*. Barbier in 45 *diphtheria* autopsies found 23 cases of cardiac thrombosis (chiefly right auricular); these cases were considered as resulting from mural endocarditis due to the "diplococcus hemophilus perlucidus." Cohn[5] has reported a fatal case of endocarditis following *chancroid*, both lesions culturally exhibiting the staphylococcus pyogenes aureus.

Pneumonia heads the list of all diseases complicated by severe endocarditis (Osler). Acute endocarditis has been attributed to pneumonia as follows:

Abraham	2 out of		9 cases	
Banti	8 " "		22 "	
Desse	14 " "		34 "	
Harbitz	9 " "		43 "	
Traux	1 " "		6 "	
Kanthack and Tickell	14 " "		84 "	
Lenhartz	5 " "		38 "	
Jackson	1 " "		5 "	
Waller	1 " "		21 "	
Weichselbaum	6 " "		33 "	
Osler	54 " "		209 "	(Ulcerative)

Total.......................... 115 out of 504 cases (22 per cent.)

Preble,[6] basing his statement on collected statistics, states that the pneumococcus is something over twice as apt to involve the aortic valves as other bacteria, and about one-third as apt

[1] Deut. med. Woch., May 22, 1902.
[2] Nordiskt Med. Arkiv., 1909, xli, No. 3.
[3] Perroud: Weill's Traité clinique des mal. du cœur chez les enfants.
[4] Dublin Jour. Med. Sci., 1907.
[5] Cohn: Jour. Amer. Med. Assoc., 1909, 47, p. 1106.
[6] Preble: "Pneumonia and Pneumococcic Infections," Chicago, 1905, p. 133.

to involve the mitral, while it attacks the tricuspid twenty times as often. The last fact is probably influenced by the special physical conditions which result from pulmonary consolidation. Pneumococcus endocarditis is twice as common in women as in men, and about three-fourths of the cases are ulcerative in character, while lesions of the right heart are more common than in other varieties of endocarditis. The aortic and pulmonary valves are involved more frequently than in other forms of the disease. Among 32,894 cases of pneumonia collected from the literature, 149 cases of acute endocarditis were reported, and among 2,722 pneumonia autopsies acute endocarditis occurred 158 times.[1] The pneumococcus generally produces large, isolated, friable, pedunculated vegetations, which on being detached leave but a small ulcerated surface. The streptococcus, on the other hand, often causes extensive ulceration covered by small verrucose excrescences, at times hemorrhagic and necrotic. Billings,[2] in a study of 14 cases of chronic infectious endocarditis, found 11 due to the pneumococcus, 3 to the streptococcus. Culturally the former organism showed distinct differences from the type which ordinarily causes pneumonia. The origin of infection was as follows: Pneumonia 1, tonsillitis 2, alveolar abscess 2, influenza 1, no discoverable cause 8. We are thus gradually coming to realize the fact that relatively unimportant infections of the nares, naso-pharynx, ears, mouth, gums, etc., may be the portal of entrance for the most severe type of endocardial inflammation.

As has been intimated, pneumococcus endocarditis is apt to be rapidly fatal. Acute cases do not usually last over three months, although Fränkel has reported a case of pneumococcus endocarditis lasting six months.[3] In Rosenow's experiments the lesions were generally progressive, though healing did occur. He states that "a close relationship exists between the biologic characters of the bacteria and their ability to produce endo-

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[1] Statistics collected by the author.
[2] Billings: Arch. Int. Med., 1909, iv, No. 5.   [3] Fränkel: Deut. med. Woch., 1900.

FIG. 7.—ACUTE INFECTIVE ENDOCARDITIS.

The aortic leaflets are thickened, shriveled, perforated, and show extensive ulcerative tissue destruction with little thrombosis. Beneath the aortic leaflets the ulceration is beginning to extend downward toward the mitral valve.

carditis in the class of cases observed." "The bacteria isolated, while having little or no pathogenic power to animals, and being susceptible to phagocytosis, present definite evidence of being immunized against the antibodies of the individual host, thereby perhaps overcoming the resistance of the latter."

In a series of cases of pneumococcus endocarditis studied by Rosenow[1] the mitral and tricuspid valves were mostly diseased, a state of affairs which he attributes to the presence of capillaries in these valves favoring embolism.

The exact distribution in Preble's cases of endocarditis in pneumonia was as follows:

		Per Cent.
Aortic only	56	39.7
Mitral only	40	28.3
Aortic and mitral	20	14.1
Tricuspid only	12	8.5
Pulmonary only	5	3.5
Aortic, mitral, and tricuspid	5	3.5
Mitral and tricuspid	2	1.4
Aortic and tricuspid	1	0.7

In Jürgensen's collection we find:

	Per Cent.
Aortic only	18.7
Mitral only	66.3
Aortic and mitral	9.2
Tricuspid only	0.4
Pulmonary only	2.3
Aortic, mitral, and tricuspid	1.0
Mitral and tricuspid	1.8

Aufrecht gives the following data regarding the distribution in relation to age, as well as the distribution of pneumonia itself:

Decade.	Pneumococcus Endocarditis. Number of Cases.	Per Cent.	Pneumonia. Per Cent.
First	2	1.4	6.8
Second	8	5.7 } 11.9	22.2 } 58
Third	15	10.8	29.0
Fourth	42	30.4	17.0
Fifth	27	19.5 } 70.9	13.0 } 35.5
Sixth	29	21.0	5.5
Seventh and over	15	10.8	6.0

Chorea, another disease which has lately been added to the list of infections, is a common cause of endocarditis. Thayer[2]

[1] Rosenow: Jour. Infect. Dis., 1909, p. 245.   [2] Thayer: Jour. Am. Med. Assoc., 1906, p. 1352.

in 689 cases of chorea found cardiac murmurs in 235 (40.5 per cent.); cardiac involvement was more frequent during second attacks and in those cases which had had rheumatic fever. Forssner[1] was able to trace the subsequent history of 28 chorea cases for periods of from fifteen to twenty-two years, and found that 5 showed pronounced heart disease, while 7 had died of it. Among 35 cases of rheumatic fever thus followed, 17 developed heart disease and 7 had died as a result.

The importance of the *gonococcus* as a cause of acute endocarditis has been justly much emphasized since the cultural demonstration of the organism in the blood during life, by Thayer and Blumer in 1895. Before that time the organism had been found on the valves by v. Leyden, and even as far back as the time of Ricord and Brandes the association of endocarditis and urethritis had been noted. In 1903 Kuelbs[2] collected from the literature 49 cases of endocarditis due to the gonococcus, in 28 of which the aortic valve was affected, the mitral in 8, the pulmonary in 6, and the tricuspid in 1. Gonococcus endocarditis is often very severe, producing large vegetations, deep and extensive ulceration, and at times myocardial involvement. Emboli appear to be infrequent. It more frequently complicates gonorrhea in the male than in the female. Although disease of the myocardium and endocardium may be caused by this organism, endocardial disease is more commonly the result of this infection. Sometimes, however, mild attacks do occur, and in these the mitral valve is more often involved. The severe form is usually associated with other metastatic manifestations, such as arthritis, etc. At autopsy grayish-red, easily detachable vegetations are usually found near the margins of the valves, which occasionally extend to the endocardium beyond. The gonococcus is sometimes tinctorially, less often culturally, demonstrable. Mixed and secondary infections occasionally occur. Valvular involvement is generally

[1] Forssner: Jarhb. f. Kinderheilk., Jan., 1910, lxxi.
[2] Kuelbs: Wien. klin. Woch., 1907, xx.

not multiple. A lethal outcome is the rule, although some cases recover. Irons[1] states that there are now on record some 120 cases of gonorrheal endocarditis, in several of which pericarditis was also found. The infarcts rarely suppurate and petechiæ are infrequent.

Although the occurrence of endocarditis and *tuberculosis* coincidently is by no means as exceptional as was once supposed, and although verrucose endocarditis has been experimentally produced by the tubercle bacillus,[2] yet true tuberculous endocarditis is distinctly rare. Marshall[3] makes five classifications to cover the relationship of the two conditions. (1) Miliary tuberculosis; (2) true tuberculous endocarditis; (3) tuberculous cardiac thrombosis; (4) tuberculous endocarditis secondary to myocarditis; (5) toxic tuberculous endocarditis.

Unfortunately the majority of available statistics, including my own,[4] which deal with the occurrence of recent endocarditis in pulmonary tuberculosis, give no information regarding the microscopic findings or bacteriologic examinations. The frequency with which this condition has been encountered is shown in the appended tabulation:

	TUBERCULOUS AUTOPSIES.	RECENT ENDOCARDITIS.	PER CENT.
Teissier	100	32	32.0
Schultze	6,937	67	0.966
Osler	216	12	5.5
Kidd	500	6	1.2
Norris	1,764	16	0.9
Fenwick	1,560	13	0.7
Otto	185	4	3.1
Dittrich	403	1	0.24
	11,665	151	1.2

Doubtless in the majority of the above cases the acute endocarditis was due to other causes than the tubercle bacillus. In one of Osler's cases fresh tubercles were found upon the mitral leaflet, but no tubercle bacilli could be demonstrated in the sections. Kidd and Councilman also failed to find them. Even when the bacilli can be demonstrated, it is perfectly possible that their presence is

[1] Irons: Arch. Int. Med., 1910, p. 601.
[2] Michaelis and Blum: Deut. med. Woch., 1895.
[3] Marshall: Johns Hopkins Hospital Bull., 1905, p. 303.
[4] Norris: Am. Jour. Med. Sci., Oct., 1904.

simply accidental, as a roughened endocardium would present a favorable ground for the lodgment of micro-organisms carried thence by the blood-stream.

Slight degrees of simple sclerotic endocarditis are met with very commonly in pulmonary tuberculosis, and are presumably due to the toxemia which is present in the chronic variety of this disease. The researches of Auclair [1] have shown that the metabolic products of the tubercle bacillus possess sclerogenetic as well as necrogenetic properties, which would readily account for the endocardial thickening. Boinet and Romary's [2] experiments indicate that bacterial toxin, even in the absence of bacteria themselves, and without the addition of trauma, are capable of producing changes in the endocardium and aorta.

"Ectasine," the vasodilatory substance which Bouchard has shown to be a constituent of the tuberculous toxin, by producing vascular relaxation would favor diapedesis of the leukocytes, thus paving the way for sclerogenous processes.

Teissier has enunciated the belief that mitral stenosis is frequently produced by the prolonged action of the tuberculous toxin upon the endocardium, which in time results in a narrowing of the valvular orifice, and states that this form of valvular lesion exerts an inhibitory effect upon the pulmonary disease. If such an inhibition exists, it is more probably due to the increased resistance which the bodily tissues have acquired through the prolonged presence of the toxin in the system than to the mechanical action of the stenosis. Chartier [3] remarks that this sclerogenous tendency is not tuberculosis, but the index of immunity versus tuberculosis.

A tuberculous process may of course be engrafted upon a pre-existing valvulitis of different etiology, or the condition may be reversed. An interesting case has been reported by Débove; [4] an individual aged thirty-four years died in a cachectic condition, and at autopsy tubercle bacilli were found in the blood and in the mitral vegetations, no tuberculous lesions being encountered elsewhere.

Heller, Cornil, and Kundrat were among the first to describe tuberculous endocarditis, but the credit of the first definite and accurate report of this condition belongs to Tripier, who, in a case of miliary tuberculosis, found a small nodule on the anterior leaflet of the mitral valve which showed the characteristic cellular changes upon microscopic examination, as well as the tubercle bacillus itself. Some time afterward v. Leyden reported four similar cases, in one of which the condition was diagnosticated ante mortem. Lion, and Londe and Petit demonstrated tubercle bacilli in the valvular endocardium, but derived negative results from inoculation experiments. Similar results were obtained by Etienne, de Thiry, Benda, Poncet and Dor, Ferrand and Rathery. Michaelis and Blum were the first to succeed with inoculation by producing tuberculous endocarditis in rabbits; and, finally, Braillon and Jousset demonstrated tubercle bacilli in

[1] Auclair: Arch. med. exper., 1900, p. 189.
[2] Boinet and Romary: Ibid., 1857, p. 902.
[3] Chartier: Rev. de la Tuberculose, Feb., 1904.
[4] Débove: Gaz. des Hôpitaux, 1903.

the blood of a man dying of primary tuberculous endocarditis, the only other evidences of this infection having been a few pleural adhesions. Tuberculous endocarditis usually assumes a verrucose, but sometimes an ulcerative form. According to Benda, the majority of the cases have their origin in a miliary infection, which happens to become localized upon the valves, being in this respect analogous to the condition described by this author as tuberculous endangeitis. In searching through the records of the Philadelphia Hospital among 1,606 tuberculosis autopsies two cases were found which were designated as "tuberculous endocarditis"; small tubercles had been found upon the valves, but apparently no microscopic examination had been made.[1]

The bacillus typhosus is one of the rarer causes of endocarditis. When endocarditis occurs in typhoid fever, it generally results from mixed infections. Experimentally endocardial lesions have been produced by the typhoid toxin by Di Vecchi. As a rule, however, the myocardium suffers more in typhoid fever than the endocardium, just as it does in diphtheria and in influenza.

Acute endocarditis in *malaria* is extremely rare. The misconception regarding this fact has been due to the fact that the chills and fever of malignant endocarditis have been mistaken for plasmodial infection.

Subacute, insidious endocarditis occurs frequently in the subjects of arteriosclerosis, chronic valvular, renal, or hepatic disease, also in mild cases of rheumatic fever or of tonsillitis. A low grade of endocardial inflammation continues for a long time, doing more and more valvular damage, until finally attention is called to the seriousness of the case by increasing fever, anemia, or an attack of broken compensation. Blood-cultures in these cases often yield streptococci of low virulence or of atypical appearance. Slight degrees of fever of prolonged duration may be constantly or intermittently present.[2]

Chronic Infective Endocarditis.—Osler has described a series of ten cases, in one of which the process lasted thirteen months. Of course, it is hard to differentiate between subacute and chronic

[1] For further bibliography of tuberculous endocarditis see article by the author in Am. Jour. Med. Sci., Oct., 1904.
[2] See "901 cases of Chronic Endocarditis with Especial Reference to Fever," J. S. Thacher, Am. Jour. Med. Sci., Jan., 1906.

FIG. 8.—ACUTE INFECTIVE ENDOCARDITIS.

CLINICAL NOTES: Case of a man aged twenty-one years, with the physical signs of aortic and mitral insufficiency with nephritis.

PATHOLOGIC NOTES: *Acute infective endocarditis* with hypertrophy and dilatation of the heart. Passive congestion of the lungs, liver, etc.

The heart weighs 670 gm. *The aortic leaflets are covered with large vegetations of recent origin. Similar although smaller vegetations are also found on the left ventricular wall and upon the mitral valve.* (Philadelphia Hospital, vol. xxi, p. 256. Physician: Dr. J. Sailer. Pathologist: Dr. D. J. Wilson.)

cases. No exact dividing-line can be drawn between the point at which a subacute infection ends and chronicity begins. In the above mentioned cases, which were all fatal, embolic manifestations occurred in four, blood-cultures were sterile in three, showed streptococci in two, and staphylococci in one instance.

Cultures made in 66 cases from the vegetations and heart's blood in 107 cases of acute endocarditis at the Pennsylvania Hospital showed the following micro-organisms:

Diplococcus lanceolatus	10
Staphylococcus pyogenes aureus	10
Bacillus coli communis	9
Streptococcus pyogenes	10
Pneumococcus	3
Bacillus typhosus	2
Micrococcus citreus	1
More than one species	6
Gonococcus	1
Meningococcus	1
Bacillus proteus vulgaris	1
A chromogenic bacillus	1
Atypical streptococcus	1
Unidentified species	1
Sterile cultures	7
Contamination	2

(In 41 no cultures were made.)

As compared with the diphtheria and the tubercle bacillus, the staphylococcus pyogenes aureus shows much greater coagulogenetic power.[1]

These 107 cases occurred among 1,300 general autopsies. Valvular involvement was as follows: aortic, 25; mitral, 47; both, 23; aortic, mitral, and tricuspid, 2; mitral and tricuspid, 4; tricuspid, 3; pulmonic, 1 (gonococcus); all valves, 2. Sixty-five of these cases showed also a chronic endocarditis, resulting from previous infection (60 per cent.). In nearly every instance the acute infection localized itself upon a valve which had already been diseased.

At the Philadelphia General Hospital among 8,640 autopsies, acute endocarditis occurred as follows: aortic, 164; mitral, 143; tricuspid, 15; pulmonic, 7; mural ulcerative, 6; vegetative, 5.

At St. Bartholomew's Hospital[2] among 19,904 medical in-patients there were 115 cases of infective endocarditis. Valvular involvement was as follows: Mitral only, 38; aortic only, 22; both, 63; mitral, aortic, and tricuspid, 14; mitral, aortic, and pulmonic, 7; mural endocarditis—auricular 43, ventricular 8.

[1] Thorel: Lubarsch and Ostertag's Ergebnisse d. allg. Path., 1907, p. 483.
[2] Horder: Quart. Jour. Med., 1908, ii, 289, 324.

Most of the cases occurred between the ages of twenty and forty years, the distribution between the sexes being about equal.

The cause of death in the last-named cases was as follows: Circulatory failure, 66; coma, 23; sudden death from embolism or changes in the heart itself,—rupture of aneurismal valves, septal perforation, rupture of the heart,—19; uremia, 18; exhaustion, 8; delirium, 5.

Embolism in endocarditis was unrecognized previous to Virchow's description; since that time it has been considered one of the most direful consequences of endocarditis. Emboli are classified, first, according to their origin as endogenous and exogenous, and, second, according to their nature as simple or infective. In a study of 250 cases of embolism occurring in heart disease at the medical clinic at Zürich, Ginsburg[1] found 110 cases (44 per cent.) in men, 56 per cent. in women, the age distribution being as follows:

10 to 20 years..........................	8 cases,	3.2 per cent.
21 to 30 "	33 "	13.2 "
31 to 40 "	21 "	8.4 "
41 to 50 "	44 "	17.6 "
51 to 60 "	59 "	23.6 "
61 to 70 "	59 "	23.6 "
Over 70 "	26 "	10.6 "

One hundred and ninety-eight occurred in cases of endocarditis, 30 in cardiac hypertrophy and dilatation, 17 in myocarditis, 5 in simple "cardiac insufficiency." Among the first-named class the mitral valve was diseased in 100 cases (50.8 per cent.), the aortic in 19 (9.6 per cent.), the mitral and aortic in 43 (21.7 per cent.), the mitral and tricuspid in 14 (7 per cent.), the mitral, aortic, and tricuspid in 17 (8.6 per cent.), the aortic and tricuspid in 1, and all valves in 2 instances. It will be noted that the left heart was the source of emboli in 79, and the right in 13 cases. The distribution of the emboli was as follows: Kidneys, 62; spleen, 23; brain, 15; lungs, 14; mucosa of the intestines, 3. Sperling's statistics based on 300 cases of endocarditis are much the same. In all, embolism was noted in 84 cases; in 76 cases left-sided lesions were the cause, the distribution being as follows: Kidney, 57; spleen, 39; brain, 15; digestive tract, 5; skin, 4.

Clinical Considerations.—While some of the severer cases of acute endocarditis, with hectic fever, tachycardia, cardiac murmurs, and local evidences of infarction are easily diagnosticated, the less fulminating cases are too easily and too often overlooked.

[1] Ginsburg: Deut. Arch. f. klin. Med., 1901, lxix, 606.

Recent investigations have shown that subacute bacteremia with progressive endocardial inflammation may go on for weeks and months while the patients are still up and about. From one to five months may elapse between the onset of acute endocarditis and the symptoms pointing to valvular lesions.[1] All autopsy statistics demonstrate the frequency with which acute endocarditis is diagnosticated as typhoid fever, uremia, chronic endocarditis, pneumonia, malaria, influenza, tuberculosis, etc. In the hospital

[1] Four cases with three autopsies, reported by Leclere, Lessieur, and Mouriquand, Lyon Medic., 1906, No. 51.

FIG. 9.—ACUTE MURAL ENDOCARDITIS.

F. F., female, aged eleven years. (Philadelphia Hospital. Physician: Dr. S. S. Cohen. Pathologist: Dr. Funke.)

CLINICAL NOTES: Previous diseases, measles, diphtheria, typhoid fever.

PHYSICAL EXAMINATION: Cyanosis, dyspnea, cervical pulsation, marked precordial bulging, with a tremendous heaving pulsation. Apex-beat in the seventh interspace in the anterior axillary line. A pronounced diastolic thrill is felt in the second and third interspaces. Marked enlargement of the cardiac dullness to both right and left. Two murmurs are heard, the diastolic being loudest at the pulmonic area. It is very high-pitched and transmitted down the sternum. A loud, somewhat musical murmur is heard at the apex and transmitted to the axilla, which does not quite replace the first sound. At the aortic area a faint tone is heard suggestive of a friction sound. A loud systolic, probably tricuspid murmur is noted at the ensiform cartilage. The liver is enlarged, but does not pulsate. Hemoglobin, 45 per cent.; erythrocytes, 2,500,000. The urine contains albumin and hyalin and granular casts. *Death* occurred gradually after a considerable hemoptysis, and with increasing failure of compensation.

PATHOLOGIC DIAGNOSIS.—*Acute ulcerative endocarditis* of the mitral leaflets and of the posterior wall of the left auricle. Perforation of the pulmonary leaflet. Adhesion of the aortic leaflets. Hypertrophy and dilatation of right ventricle and of the left auricle. Atheroma of the aorta.

HEART: Weighs 480 gm. The right auricle is distended with black blood-clots and its cavity is large. Its wall measures 0.5 cm. at its thickest portion and its muscle is firm. The endocardium is opaque and presents reddish discolorations in some areas. The mitral orifice measures 3 cm. in diameter. The right ventricle has a separate apex and seems large; its wall measures 1 cm., its color is bright red, and its endocardium is smooth and glistening. The tricuspid leaflets show slight thickening along the line of contact. The pulmonary valves are incompetent owing to a perforation in the posterior leaflet. The left auricle is very large; its muscle, which is firm and pale, measures 5 mm. *Beginning at the mitral orifice and extending along the posterior wall of the auricle is an area 4 x 6 cm., of closely set, irregular, pinkish vegetations, many of which measure 3 mm. in height,* and which have somewhat the appearance of necrotic bone. The left ventricle is also large, has a distinct apex, and measures 16 mm. in thickness. On the anterior surface of the ventricular endocardium are two irregular circular areas, one measuring 6 mm., the other 3 mm. in diameter, consisting of elevated granular, pinkish vegetations. The smaller of these is superficial; the larger extends almost to the pericardial surface. The auricular aspect of the mitral valve presents an appearance similar to that of the posterior wall of the left auricle. The edges of the leaflet are comparatively smooth, although vegetations are occasionally noted. At the junction of the posterior and internal leaflets a perforation is seen.
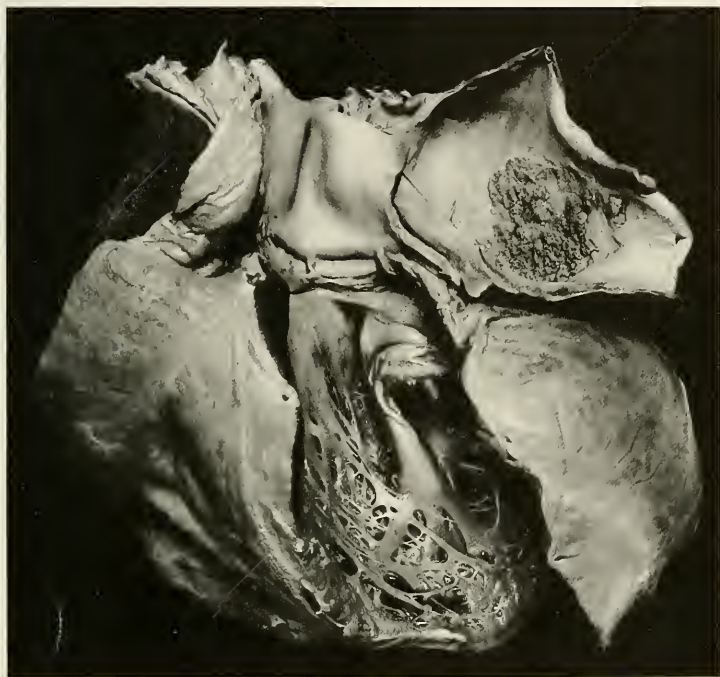
(Photograph by Dr. A. R. Allen.)

FIG. 9.

statistics this point is certainly underestimated, because of the greater facilities for laboratory methods at the command of the clinicians in a modern hospital. Blood-cultures when carefully and repeatedly made are of the greatest assistance in arriving at correct conclusions.

Among 107 cases of acute endocarditis autopsied at the Pennsylvania Hospital the endocarditis was correctly diagnosticated in 24 instances. In many cases the true condition was completely overshadowed by other conditions. The following diagnoses were recorded: typhoid fever, 12; pneumonia, 9; chronic endocarditis, 14; septicemia, 3; chronic nephritis, 4; acute pericarditis, 3; miliary tuberculosis, 1; congenital heart disease, 1; rheumatic fever, 1; renal calculus, 1; asthma, 3; etc. Nine cases were admitted in a moribund condition, and no diagnosis established. These figures cast no reproach upon the physicians of the hospital, who, as is well known, stand in the foremost rank of the Philadelphia medical world. They merely illustrate the insidious nature of the pathologic process which we have been discussing. It should also be borne in mind that in the vast majority of these cases the diagnoses made were correct. The endocarditis was simply a complication of other diseases, which did not manifest itself by prominent symptoms or physical signs.

CHRONIC INFECTIVE ENDOCARDITIS

Bacteriology.—Horder,[1] who has been more fortunate than most other investigators, states that with careful technic, positive blood-cultures can be obtained intra vitam sooner or later in 90 per cent. of all cases of infective endocarditis. He has published analyses of 40 cases, in 27 of which the bacteriologic findings were substantiated at autopsy as follows: Streptococcus, 26; bacillus

[1] Details of Horder's technic, Practitioner, Nov., 1905. "Treatment with Vaccines" (Horder), Practitioner, 1908, p. 714. Positive blood-cultures in 28 consecutive cases: Streptococcus, 18; bacillus influenzæ, 5; pneumococcus, 3; gonococcus, 1; staphylococcus, 1. Hence the streptococcus type caused 65 per cent., or, if including pneumococcus, 77 per cent., of all cases. See also Libman and Celler (43 cases): Trans. Assoc. Amer. Phys., May, 1910.

influenzæ, 5; pneumococcus, 5; gonococcus, 2; staphylococcus albus, 1; unidentified, 1.

It will be observed that the genus streptococcus causes 77 per cent. of the cases (some 6 cases in which bacillus influenzæ was successfully cultivated from blood are now on record). He quotes 100 postmortem cultures from the heart's blood as corroborating his intra-vitam findings.

Following surgical infections the staphylococcus aureus is more frequent. These infections, which are seen in osteomyelitis, etc., are often rapidly fatal. Differentiation of the varieties of streptococci based upon certain metabolic reactions seems to show that the streptococcus generally found in endocarditis is not the same species which is found in acute suppurative conditions.

Horder's investigations indicate that infective endocarditis is generally due to streptococci of low virulence, such as those normally found in the saliva and the intestinal tract, a fact which explains the protracted insidious character of this so frequently overlooked process. "It may be that the very lowness of the virulence of these habitual saprophytes of the alimentary canal accounts for the lack of efficient resistance on the part of the patient, there being no adequate stimulus to call forth the defensive mechanisms necessary for the destruction of the cocci" (Horder).

Horder suggests the following classification:

I. Latent infective—a terminal condition, in old valvular cases, etc.

II. Fulminating infective.

III. Acute infective—the clinical picture is that of pneumonia, it is often due to pneumococcus.

IV. Subacute infective—the commonest variety associated with a gradual development of dyspnea, weakness, arthritis or chorea, etc., lasting from two to six months.

V. Chronic infective: Insidious—ambulant cases—organisms of low virulence—streptococcus fecalis often found.

The valvular form of *syphilitic endocarditis, except when it follows aortitis,* is generally secondary to syphilitic myocarditis as the result of direct extension. Parietal lesions are more frequent than valvular alterations. Macroscopically they often show no sclerotic changes. Occasionally, however, as in a case reported by Duckworth,[1] minute gummata occur. The seat of predilection

[1] Duckworth: Lancet, 1895.

FIG. 10.—ACUTE ULCERATIVE MITRAL AND AORTIC ENDOCARDITIS.

Negro. (Pennsylvania Hospital. Autopsy No. 328. Pathologist: Dr. Longcope. Physician: Dr. A. Stengel.)

CLINICAL NOTES: Twenty-three years old. Denies venereal disease. Has never been ill before, except with pneumonia six months ago. For the last four days has had dyspnea, chills, and vomiting.

Heart dullness much enlarged. Apex-beat forcible and diffuse. Systolic thrill near apex. Pulmonic second sound accentuated. A loud, long, diastolic murmur over the heart, and through both sides of the chest.

PATHOLOGIC NOTES: *Acute ulcerative mitral and aortic endocarditis.* Acute myocarditis; acute hemorrhagic pericarditis, etc.

HEART: is much enlarged; feels like thick-walled cyst, and is rather rounded in shape. It collapses about the hand when held at the apex. Epicardium: irregular areas of opaque, white thickening over surface of left ventricle. Sometimes these follow the vessels, which are otherwise not very prominent. Beneath the endocardium, heart has mottled yellow appearance, and shows numerous ecchymotic hemorrhages at the vascular terminations. Tricuspid and pulmonary valves normal; the orifices measure respectively 13 and 7.5 cm. in circumference. Right ventricle, 4 mm., left ventricle distended by clot. Left auricle slightly dilated. *Mitral valve is seat of extensive ulcerative endocarditis; the vegetations, situated especially on the auricular surface, are yellowish, soft, and friable. They frequently measure 1 cm. in diameter, and project high above the valve surface. Smaller vegetations on the surface of the auricle.* From the free border of the aortic valves two large pendulous thrombi hang into the ventricle, measuring 2 cm. in length, the valve being much ulcerated at their point of attachment, the thrombi covering the ulceration. On the endocardium of the ventricle there is a patch 2 cm. in diameter below the insertion of the aortic valves, covered with small yellowish accumulations. Aortic valves thickened and ulcerated along their free margins. Heart-muscle soft and friable, pale brownish-gray. Sprinkled through the section are minute yellow points; one or two large ones (1 to 2 cm. in diameter). *Papillary muscles and columnæ carneæ of both ventricles much flattened. Left ventricle 1 cm.* Definite cardiac contractions are elicited by pinching muscle with forceps; especially is this true of the papillary muscles (one and three-fourths hours after death).

MICROSCOPIC EXAMINATION: Muscular striæ poorly marked. Nuclei: large, pale, indefinite, and in some places surrounded by clear spaces. Muscle-cells show moderate fragmentation; many are filled with large vacuoles. Slight hemorrhages are scattered through the section, beneath the endocardium and pericardium. They are fairly extensive. The vacuole-like degeneration is most marked near the hemorrhages, and everywhere occurs in patches. At one point a mass of polymorphonuclear leukocytes is seen in the myocardium; surrounding it there are some hemorrhages and much degeneration of muscle-cells. In the mass of muscle degeneration the muscle-nuclei have entirely disappeared.

Acute parenchymatous degeneration of the myocardium.

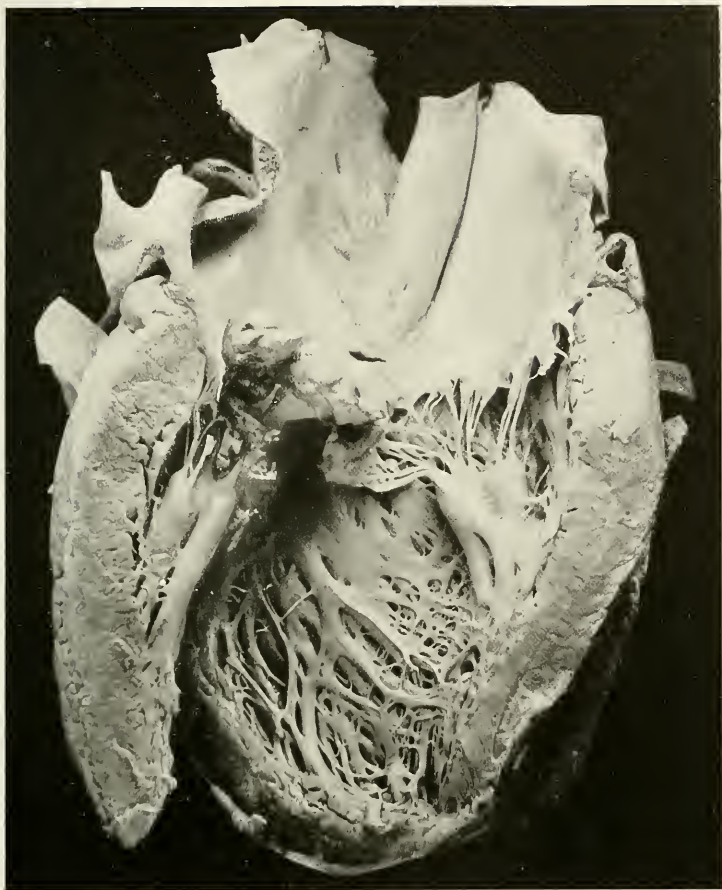The *pneumococcus* was obtained from the heart's blood and the vegetations.

FIG. 10.

seems to be the left ventricle. When the valves are attacked, the lesions are often limited to a valve or part of a valve. Sclerotic changes—retraction, etc.—ultimately result. Taneff[1] collected 95 cases of syphilitic endocarditis, in 10 of which, however, the etiologic factor was questionable.[2] (Compare chapters on aortic endocarditis and cardiac syphilis.)

Trauma may produce valvular lesions in two ways: Either (a) by rupture of a papillary muscle or chorda tendineæ, or (b) by rupture of the endocardium, with the production of thrombi or subendothelial hemorrhages. Injuries which produce such valvular damage generally consist of crushing forces or violent blows. It is very doubtful whether mere sudden increase in vascular tension as a result of heavy lifting, etc., is capable of rupturing any part of a healthy heart. Such cases are reported, but are presumably the result of localized weakening through antecedent pathologic processes. Blows inflicted in the precordial

[1] Inaug. Dissert., Berlin, 1896.

[2] Complete literature by Herxheimer: Lubarsch and Ostertag's Ergebnisse der allg. Path., i, 1906.

FIG. 11.—ACUTE VEGETATIVE AND CHRONIC ENDOCARDITIS.

W. R., male, aged forty-six years. (Pennsylvania Hospital. Autopsy 1165. Physician: Dr. J. A. Scott. Pathologist: Dr. Krumbhaar.)

CLINICAL NOTES: The patient, who is an alcoholic, has been ill for two days with cough and chills. Lungs: full of râles. An apparent pulmonary consolidation at the left base. Cyanosis, tremors. Heart negative. *Death* two days later, suddenly, apparently from acute cardiac dilatation.

PATHOLOGIC DIAGNOSIS. Lobar pneumonia. *Acute vegetative and chronic endocarditis.* Pulmonary congestion and edema.

PERICARDIUM: Contains 30 c.c. of turbid yellow fluid, with a few fibrinous flakes.

HEART: The heart is much enlarged (490 grams), especially to the right. It is greatly distended with currant-jelly and pinkish chicken-fat clots. Except for a patch of thickening on the posterior surface, the epicardium is negative. The mitral orifice admits three fingers. *The left ventricle is enlarged, and measures from 14 to 18 mm.;* it is somewhat pale and friable. The endocardium is smooth. *All three aortic cusps show markedly a vegetative growth. The cusp opposite the right coronary artery shows the smallest vegetation, which is limited to the cardiac side of the valve. The growth is yellowish, irregular, nodular, and in some places calcareous, the greater part, however, being semitransparent, soft, and friable. The vegetations on the other valves are soft and gray. They are irregularly nodular with a finely granular surface. One of them measures 1 cm., the other 2.5 cm. in length. The large vegetation has a base about 1 cm. in breadth, so that it is freely movable in the left ventricular cavity. The mitral valve shows slight thickening. The aortic cusp at the highest point of its attachment shows a similar thickening. The coronary arteries are large, thin, and patent. The valvular orifices measure as follows: Tricuspid, 12 cm.; mitral, 12 cm.; pulmonary, 8 cm.; aortic, 8.5 cm.*

Fig. 11.

region may produce endocardial, pericardial, or myocardial lesions, even when the skin and thorax remain uninjured. Among 34 animals experimentally studied by Kuelbs[1] the following lesions were produced: valvular damage, 21; distributed—mitral 12, aortic 7, tricuspid 5, pulmonic 4. All of these lesions were hemorrhagic. Actual valvular rupture occurred once. In no instance were any of the chordæ tendineæ torn. Myocardial damage followed in 15 cases and consisted chiefly of hemorrhages or tears in the septum. In one case there was cardiac rupture. The pericardial lesions were eleven in number, mainly hemorrhagic in character. None of the cases showed loss of compensation, and only rarely were murmurs present. Experimental valvular lesions in animals show a very marked tendency to rapid healing with simple scar tissue formations.[2] If there is a chance for infection,

[1] Kuelbs: Mitt. a. d. Grenz. der Med. u. Chir., 1909, p. 679.

[2] For trauma as a cause of endocarditis, etc., see: Stern, Ueber die traumatische Entstehung innerer Krankheiten, vol. i; Thorel, Lubarsch and Ostertag's Ergebnisse, 1907, ii, 434; Dreyfuss, Thèse de Paris, 1896; Heimann, Dissert. Berlin, 1896; Sinnuber, Deut. med. Woch., 1904, No. 32; Fränkel, Münch. med. Woch., 1905, No. 15; Marcus, ibid., No. 47; Herzfeld, Jour. Am. Med. Assoc., 1906, p. 855.

FIG. 12.—ULCERATIVE AORTIC ENDOCARDITIS.

I. S., male, white, aged forty-eight years. (Pennsylvania Hospital. No. 320 (1902). Autopsy 189. Pathologist: Dr. Longcope.)

PATHOLOGIC DIAGNOSIS: *Ulcerative aortic endocarditis. Globular thrombus attached to aortic valve.* Extensive multiple thrombosis of arteries and veins. Acute bronchopneumonia. Chronic pulmonary tuberculosis, etc.

HEART: The heart is quite small, weighs 250 grams. The epicardium contains a moderate amount of fat and two milk patches. The tricuspid, pulmonary, and mitral valves are normal. The left ventricle is very small, measuring only 7 cm. from the aortic valve to the tip; it is 15 mm. in thickness. On *the mitral cusp of the aortic valve is a large globular thrombus which measures 2 cm. in diameter, being firmly attached to the outer portion of the valve. It projects into the aortic orifice, forming as it were a complete plug for it, when the valves are in normal position.* It is mixed red and gray in color, somewhat *lobulated and firm.* The *sinus of Valsalva of the valve is filled with a recent thrombus of similar character which projects about 8 mm. above the velum of the valve. The two globular thrombi are joined by a fibrinous band.* The portions of the leaflet which are uninvolved are thin and delicate, as is also the velum. The other two valve cusps are a trifle thickened, but still delicate and evidently competent. The heart muscle is brown and firm; and the endocardium is slightly flecked with yellow. The aorta is small. The coronaries are patent.

MICROSCOPICALLY the *thrombi consist largely of erythrocytes and fibrin.*

BACTERIOLOGIC DIAGNOSIS: Heart's blood: Sterile after forty-eight hours at 36.5° C. Thrombi on aortic valve: Streptococcus pyogenes. Lung: Micrococcus lanceolatus. Thrombus from vena cava: Bacillus coli.
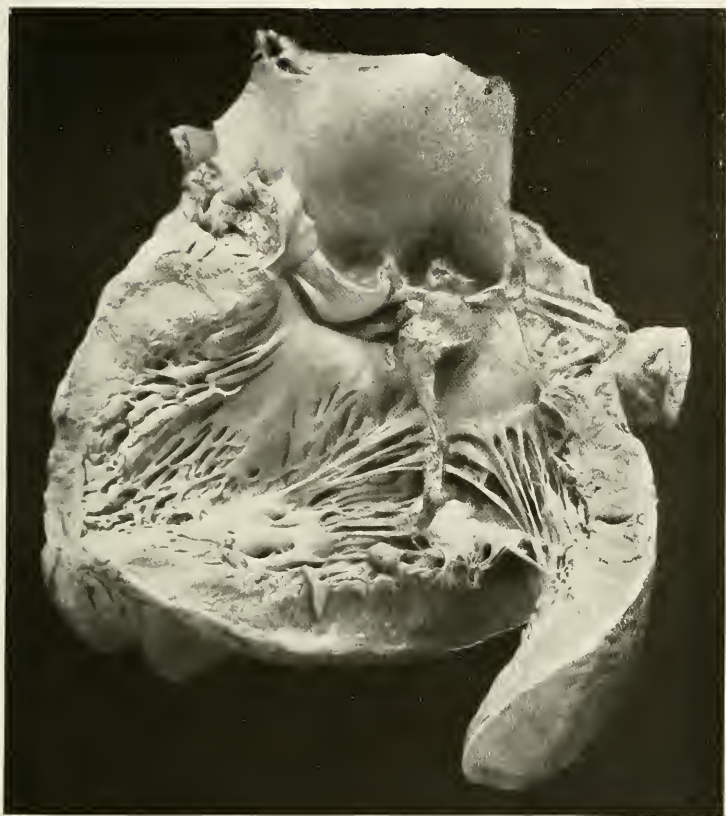
FIG. 12.

however, as when the animals are kept in dirty kennels, these injured valves not infrequently become the seat of an acute endocarditis.

A considerable number of instances of traumatic valvular disease have been recorded, as, for instance, a case of Schmidt's[1] of an aged patient falling out of a second-story window and rupturing the aortic and mitral valves.

The danger of trauma, then, in relation to endocarditis is twofold. It may reactivate a quiescent lesion, or it may prepare the soil of a previously healthy endocardium for subsequent infection. Its action may be direct, through the force of a blow, or indirect, as the result of suddenly increased blood-pressure.

The endocardial changes following infectious endocarditis are in some respects different from those due to purely mechanical causes, as in chronic valvular disease. Thus, for instance, in the latter case the line of valvular closure of the leaflets shows the principal changes; in the former, the free margins are involved.

[1] Schmidt: Münch. med. Woch., Sept. 23, 1902. Claisse and Socquet report the case of a healthy man of forty-eight years who was crushed on the chest by a heavy stone which he was trying to lift into place. The injury was followed by sudden pain and dyspnea. At autopsy five months later a ruptured papillary muscle was found. (Bull. et Mém. Soc. Méd. des Hôp. de Paris, 1908, p. 769.) Another case was reported by Marcus. (Münch. med. Woch., 1905, p. 228).

II. CHRONIC ENDOCARDITIS

THE term "chronic endocarditis" as currently applied is ambiguous. It should, of course, be limited to those cases in which an acute endocarditis has become established as a continuous progressive process; but often it is employed to designate an old endocardial lesion, even of the arteriosclerotic type, the course of which may have been completely arrested. On the other hand, we must bear in mind that in many apparently quiescent cases active inflammation due to organisms of low virulence or the fibrogenic activities of an antecedent inflammation may still be operative.

The term chronic endocarditis is generally applied to a fibrotic process which follows an acute infection. About one-half of the cases of valvular heart disease arise in this manner, the remainder, with negligible exceptions, resulting from the arteriosclerotic changes of advancing life. As in other parts of the body, destruction of tissue is followed by the formation of scars, which on the endocardium produce deformities of the valves and their orifices by contraction, induration, puckering, and adhesion, and ultimately in some cases calcification. In this manner valvular obstruction and insufficiency may be developed.

In the mitral area the occurrence of adhesions tends to fuse together the valvular curtains, and if the chordæ tendineæ are also involved, a funnel-shaped orifice results. Skrinking and fibrosis continue, thus bringing about more and more induration, shortening, and stiffening. If only partial union of the free lateral valve margins occurs, a slit-like opening is left—the "buttonhole mitral." The anterior flap of the mitral is most frequently and extensively involved, especially in the region nearest to the aortic valve, where the greatest strain occurs owing to the auriculo-ventricular and the ventriculo-aortic blood-stream. Organic mitral disease

generally follows infectious endocarditis, while, excepting syphilis, aortic lesions are more often the result of arteriosclerosis. Mitral stenosis also is very commonly a sequel of endocarditis; pure insufficiency is less often. Contraction and induration result from the organization of granulation tissue, and in this process the chordæ tendineæ and the papillary muscles often share. Calcification which results from the deposition of lime salts in the diseased areas produces roughness and inflexibility. In this process the aortic valves, especially about the corpora Arantii and along the free margins, are chiefly affected. In all cases of valvular damage the amount of calcium ions in the blood plays an important part in the degree and extent of the lesions produced. This process of calcification is nature's method of repairing weak spots and leaks, and in robust plethoric individuals she often overplays her part. As Sir James Barr puts it in speaking of the calcium ions in relation to mitral stenosis: "They raise blood-pressure, increase the force of the cardiac contractions, give rise to hypertrophy of the papillary muscles, cause violent collision of the mitral cusps, increase the formation of fibrous tissue, and gradually cement and unite the edges of the cusps together."

In sclerotic endocarditis not only the valvular leaflets, but also the chordæ tendineæ and papillary muscles are affected.

FIG. 13.—ACUTE VEGETATIVE AND ULCERATIVE AORTIC AND MITRAL ENDOCARDITIS.

W. G., male, aged fifty-six years. (Philadelphia Hospital, vol. xviii, p. 142. Physician: Dr. R. G. Curtin. Pathologist: Dr. Guthrie McConnell.)

CLINICAL NOTES: A paroxysmal drunkard; was admitted with cough, edema, and dyspnea.

PHYSICAL EXAMINATION.—Heart is enlarged to right and left. A systolic murmur is heard at the apex and transmitted to the axilla. A doubtful systolic murmur is heard at the aortic area. The second sounds at the base are indistinct. The patient developed uremic symptoms and *died suddenly* during an attack of coughing associated with marked cyanosis.

PATHOLOGIC DIAGNOSIS: *Acute vegetative and ulcerative aortic and mitral endocarditis. Cardiac hypertrophy*, hydrothorax, ascites, chronic parenchymatous nephritis, etc.

HEART: Weighs 620 gm. *The middle leaflet of the aortic valve shows a vegetation 13 x 10 x 3 mm., soft in consistence, reddish-yellow in color. Smaller vegetations are seen on the other leaflets and on the mitral valve, the anterior curtain of which shows a circular ulcerated area, 10 mm. in diameter, the central portion of which has completely perforated the leaflet.* The auricular surface is covered by a large irregular vegetation. *The chordæ tendineæ show many pinhead-sized vegetations.* The pulmonary valves are normal. The tricuspid orifice is dilated.
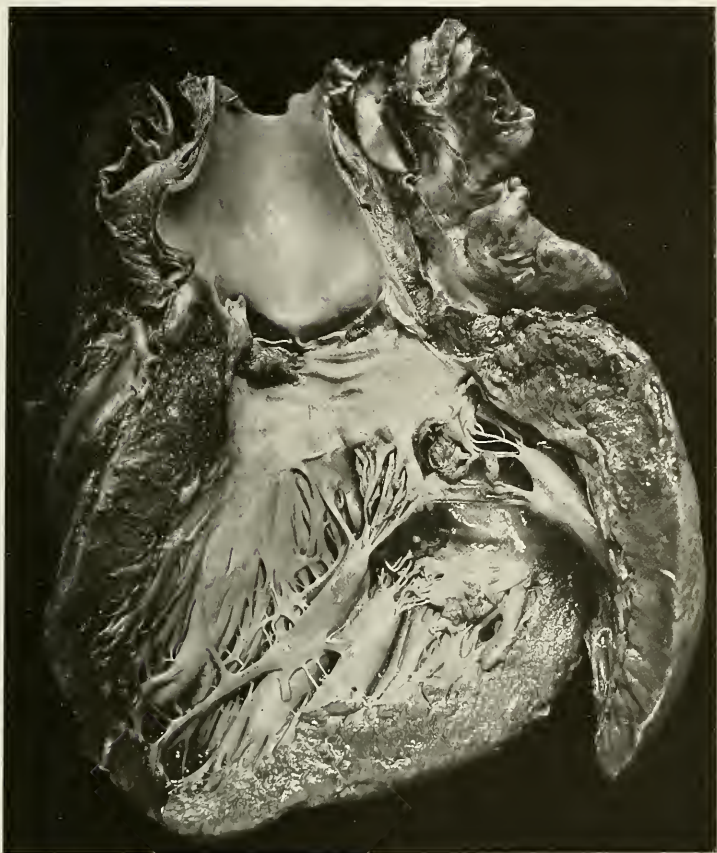
FIG. 13.

Lowenstein[1] in a study of the fibrosis of the latter was led to conclude that these fibroid changes are secondary to previous muscular degeneration, a process to which this part of the cardiac musculature seems to be especially susceptible. Actual bone formation in the valves and even the heart itself has been described.

Frequency.—The frequency of valvular disease and the type vary considerably in different statistics, at different ages, in the two sexes, and according to the etiologic factor. Thus, under forty years of age, especially in women and in children, and as the result of rheumatic endocarditis, mitral lesions are in preponderance. After forty years of age, and in men (especially syphilitics and arteriosclerotics), aortic lesions assume the predominating rôle. Andrew among 1,474 cases of heart disease found 887 (60.1 per cent.) in men, and 587 (39.8 per cent.) in women. Endocardial lesions—acute and chronic—formed 87 per cent. of the total number of cardiac ailments (pericardial 5.4 per cent., myocardial 5.5 per cent.). The greatest number of chronic mitral cases occurred between twenty and thirty years, of aortic disease between forty and fifty years, and degenerative myocardial changes after fifty years.[2] The statistics of Bollinger and of Eulenburg show that well-marked disease of the cardiac valves or orifices occurs in from 5 to 10 per cent. of all autopsies.

From a *morphologic standpoint* Dewitsky[3] has formulated the five following types of chronic valvular lesions:

I. Diffuse infiltration of the leaflets: an extension from the endocardium, inflammatory in character, the terminal phase of an acute endocarditis.

II. Lesions on the valvular edges: resulting from hypertrophy of the subendothelial layer, caused by relative insufficiency of the valves affected.

III. Lesions at the base of the leaflets: a quasi-physiologic process found with increasing frequency as life advances.

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[1] Lowenstein: Centralb. f. allg. Path. u. path. Anat., 1907, p. 385.

[2] Andrew: "Age Incidence, Sex and Comparative Frequence of Disease," London, 1909.

[3] Dewitsky: Thèse du Moscow, 1908. (See also Virchow's Archiv, 1910, cxcix.)

IV. Lesions found only on semilunar valves: arteriosclerotic in nature and extending from the vascular wall to the leaflets.

V. Lesions on the free border of the aortic valve: resulting from thrombotic changes initiated by an acute endocarditis (infectious).

(These types, though distinct, are often mixed.)

From a *clinical standpoint* the relative involvement of different valves has been reported as follows:

Observer.	Number of Cases.	Mitral.	Aortic.	Pulmonary.	Tricuspid.	Mitral and Tricuspid.	Mitral and Aortic.	Mitral, Tricuspid, Aortic.	Aortic and Tricuspid.	Indefinite.	Other Combinations.	All Valves.
Ashton (Med. News, June 30, 1894)	1024	621	221	..	11	..	171	..	..	..	..	..
Crook (N. Y. Med. Jour., 1897, 821)	478	111	65	1	6	..	15	..	..	..	..	..
Satterthwaite (Dis. of Heart and Aorta)	65	6	12	0	0	2	31	4	2	..	4	1
Chambers (Med. Times and Gazette, 1852)	367	96	107	..	10	..	121	10	2	..	6	9
Bamberger (Virchow's Arch., ix, p. 524)	211	137	45	2	1	12	9	5	..	..	..	..
Schnitt (Dissert. Jena., 1893)	210	121	37	1	2	10	33	5	..	..	..	..
Leuch (Dissert. Zurich, 1889)	241	173	21	4	..	9	34	..	..	..	..	..
Hirsch, (Mitt. a. d. Med. Klinik, Wurtzb , vol. ii, p. 305)	203	121	51	7	4	4	8	7	1	..	..	..
Köster (Dissert. Göttingem, 1883)	116	63	7	..	1	..	30	6	1	8	..	..
Leuch	67	13	13	..	..	..	..	..	..	..	..	..
Guttmann (Dissert. Breslau, 1891)	1396	934	283	2	29	10	110	1	..	27	..	..
Sperling (quoted Gibson)	300	157	40	0	3	9	71	16	..	..	4	1
Middleton (Lancet, 1889)	..	80	20	1?	3	..	..	..	..	..	..	..
Sansom	300	255	129	3	29	..	..	..	..	..	..	..
Lambert (J. A. M. A., 1908)	283	232	124	0	8	..	..	..	..	..	..	..
Olsen	..	29	26	1	5	..	..	..	..	..	..	..
Pennsylvania Hospital (autopsies)	274	84	114	1	4	12	58	..	1	0	..	..
	5535	3226	1315	23	116	68	691	54	6	35	14	11

A *valvular aneurism* consists of a "circumscribed pouching of one of the valve segments." Two varieties are met with:

(*a*) In which the whole thickness of the leaf is pouched.

(*b*) In which as the result of ulcerative endocarditis the lamellæ of the valves have become dissected apart.

Valvular aneurisms vary in size from a small lentil to a small pigeon's egg, and are occasionally multiple. The mitral valve is most frequently attacked and shows the largest aneurisms, although rupture occurs more frequently when the aortic valves are involved. In some chronic cases, instead of rupture, thrombosis of the sac occurs. (See Fig. 14.)

Clinical Considerations.—Given a case of valvular heart disease, the practitioner is called upon to determine a number of questions: The site of the lesion, whether it is obstructive, or regurgitant, or combined; whether more than one valve is involved. What is the severity of the lesion as regards actual mechanical effects? What is the cause of the lesion—infectious, arteriosclerotic, or merely functional? Is it apt to be progressive? and if so, how rapidly? Is the actual infection still continuing? The importance of the last question cannot be overestimated, and it is by no means easily answered. As has already been stated, the infection often goes on insidiously for months. Thacher has called attention to the persistence of fever in many of these cases, and Coleman has pointed out how exactly the fever curves may simulate different types of malarial infection.[1] With the possible exception of the last question the following is the most important of all: What is the state of the myocardium,—how much actual damage has it sustained, either from the infection or from the degenerative changes of age, syphilis, tobacco, etc.? The French have an axiom which well emphasizes this: "A disease of the valves is not a disease of the heart."

As to the duration of life, this of course varies greatly. In Romberg's clinic one patient was known to have lived thirty-eight years with a valvular lesion. Sir Andrew Clark in a study of 700 cases found that often there was practically no shortening of life. The emergencies of life and infectious processes are less well withstood.

When cardiac failure does occur, it is by no means rarely due
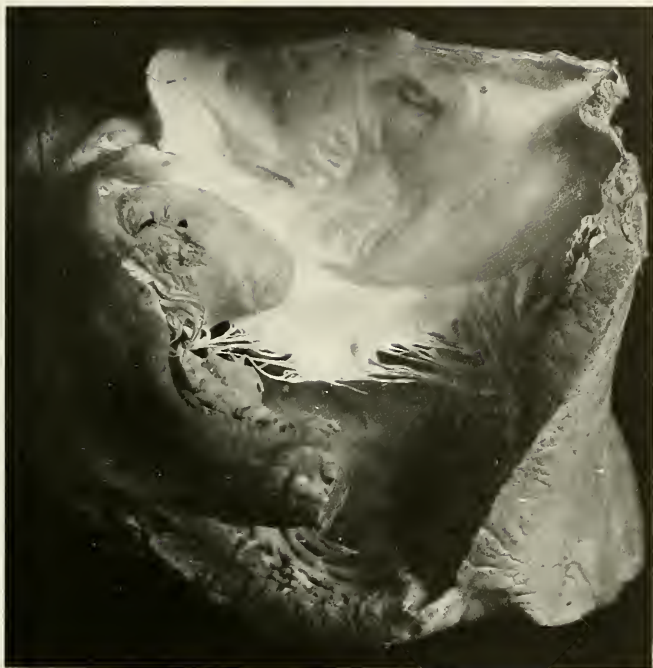
[1] Amer. Jour. Med. Sci., March, 1905.

Fig. 14.—Large Aneurism of the Mitral Valve with Fenestration.
Bulging into the auricular cavity. (Specimen from the University of Pennsylvania
Museum.)

to chronic infection, at least this is Stein's[1] conclusion, and this is borne out by the results of artificially produced valvular lesions in animals.

While combined valvular lesions are often doubly disadvantageous, they may to a certain extent be beneficial and compensating. Thus an aortic obstruction added to an insufficiency may to some extent prevent left ventricular dilatation; the mitral insufficiency which is sometimes engrafted upon an obstruction represents a certain grade of healing (Krehl).

Heredity.—A hereditary tendency to certain forms of heart disease seems to exist. Perhaps the best known type is that described by Huchard as "aortism," by which is meant the well-known plethoric, hypertensive, ultimately arteriosclerotic type of man who dies suddenly of apoplexy, and in whose family this history is very common.

The term "myocardism" has been suggested by Galli for the type of individual in whose family, although demonstrable arteriosclerosis is not a prominent feature, there is a tendency toward myocardial weakness and degeneration.[2] Virchow and Beneke pointed out that a small arterial system predisposed to infectious endocarditis.

The term "mitralism" has also been suggested as descriptive of a tendency to lesions, more especially stenosis of this orifice.

STATISTICAL DATA FROM THE PENNSYLVANIA AND THE PHILADELPHIA
GENERAL HOSPITALS

I. ENDOCARDIUM.

Mitral Valve.	PENNSYLVANIA HOSPITAL.	PHILADELPHIA HOSPITAL.
Acute simple endocarditis of mitral alone		58
Acute vegetative endocarditis of mitral alone	47	17
Acute ulcerative endocarditis of mitral alone		
Acute mitral and aortic endocarditis	23	33
Acute mitral and tricuspid endocarditis	2	4
Acute mitral, tricuspid, and aortic endocarditis	2	0
Aneurism of mitral valve (with rupture)	0	1
Anomaly of mitral valve (1 fenestration, 1 pouching, 1 supernumerary leaflets)	0	3

[1] Stein: Nordschr. Med. Arch., 1905, xlii.   [2] Galli: Berlin. klin. Woch., 1907, p. 372.

Fig. 15.—Chronic Mitral and Tricuspid Endocarditis.

B. S., female, negro, aged twenty-one years. (Philadelphia Hospital. Autopsy vol. xviii, p. 154. Physician: Dr. Hughes. Pathologist: Dr. McConnell.)

Clinical Notes: Acute *rheumatic fever* four years ago, and again two years ago. Severe leukorrhea for last four years. Denies syphilis, but shows what are apparently luetic scars. Alcohol moderately. Four years ago began to have vertigo and dyspnea, which have gradually increased in frequency and intensity, and were generally induced by exertion. For last few months has also had cough, gastric symptoms, and muscæ volitantes.

Heart dullness enlarged. Presystolic thrill within the apex, at which area a double mitral murmur is heard. Both second sounds are accentuated, especially the pulmonic. Pulse 110. Death occurred gradually from pulmonary congestion.

Pathologic Diagnosis: *Chronic mitral and tricuspid endocarditis;* chronic pleuritis; right-sided hydrothorax; congestion and edema of right lung; bilateral pulmonary infarction; diffuse nephritis.

The pericardium contains a small amount of fluid.

Heart: weighs 340 gm. Aortic leaflets, thin and transparent. *Mitral orifice barely admits tip of index-finger; its leaflets are much thickened. The tips of the papillary muscles show marked fibrosis. Pulmonary leaflets normal. Tricuspid orifice* (the lowermost on plate) *is small; leaflets thickened, and on free edges are numerous vegetations. On one leaflet there is a vegetation one inch in height, which extends directly into the opening.*

STATISTICAL DATA FROM THE PENNSYLVANIA AND THE PHILADELPHIA GENERAL HOSPITALS—(*Continued*)

	PENNSYLVANIA HOSPITAL.	PHILADELPHIA HOSPITAL.
I. ENDOCARDIUM. *Mitral Valve*—(*Continued*).		
Hematoma of mitral valve	1	1
Calcification of mitral valve	..	112
Stenosis of mitral valve	..	72
Rupture of mitral valve	0	1
Aortic Valve.		
Acute vegetative endocarditis of aortic alone	25	39
Acute ulcerative endocarditis of aortic alone		
Acute aortic and tricuspid endocarditis	0	0
Acute aortic and pulmonary endocarditis	0	3
Aortic stenosis	6	42
Aortic fenestration	2	43
Aortic calcification (ossification)	1	1
Aortic anomaly (bicuspid valve)	2	3
Aortic valvular aneurism (with rupture)	0	1
Acute endocarditis of all valves	2	16
Subendocardial hemorrhage	..	13
Subendocardial cyst	1	1
Tricuspid Valve.		
Acute vegetative endocarditis of tricuspid alone	3	15
Acute ulcerative endocarditis of tricuspid alone		
Subacute endocarditis of tricuspid	2	0
Anomaly (pouching)	0	1
Supernumerary leaflets	0	1
Fenestration	0	1
Pulmonary Valve.		
Acute vegetative endocarditis of pulmonary valve alone	1	7
Acute ulcerative endocarditis of pulmonary valve alone		
Chronic pulmonary endocarditis—sclerosis	1	44
Congenital malformation of	1	4
Fenestration	0	17
Supernumerary leaflets	1	9
Acute Mural Endocarditis.		
(*a*) Vegetative	2	5
(*b*) Ulcerative		6
Auricular thrombosis	28	25
Ventricular thrombosis		..
Tuberculous endocarditis	0	2
II. MYOCARDIUM.		
Rupture of left ventricle	0	1
Rupture of left auricle	0	2
Rupture of right ventricle	1	0
Rupture of papillary muscle, or chordæ tendineæ	1	1
Hemorrhage into myocardium	..	4
Acute hemorrhagic myocarditis	2	..
Acute suppurative myocarditis	1	5
Sarcoma of myocardium	1	4
Carcinoma of myocardium	0	4

STATISTICAL DATA FROM THE PENNSYLVANIA AND THE PHILADELPHIA GENERAL HOSPITALS—(*Continued*)

II. MYOCARDIUM—(*Continued*).

	PENNSYLVANIA HOSPITAL.	PHILADELPHIA HOSPITAL.
Tuberculosis of myocardium	1	4
Gumma of myocardium	2	1
Cardiac aneurism	6	3
Calcification of myocardium	0	2
Infarction of myocardium	2	6
Parietal thrombus left ventricle	7	..
Parietal thrombus right ventricle	7	..
Tuberculosis of aorta	1	0
Interventricular Septum.		
Ulceration of interventricular septum	..	1
Perforation of interventricular septum	2	3
Aneurism of interventricular septum	0	1
Rupture of interventricular septum	0	1
Patulous interventricular septum	4	1
Patent ductus arteriosus	1	9
Pennsylvania Hospital	1300 autopsies	
Philadelphia Hospital	8640 autopsies	

The foregoing statistics were collected from the autopsy records of the two above named hospitals. The discrepancy of some of the figures when the two sources of data are compared is largely due to the fact that at the Pennsylvania Hospital only acute cases are admitted, whereas the Philadelphia Hospital, being connected with the almshouse and the insane asylum, is filled mainly with people advanced in life.

III. DISEASES OF THE AORTIC ORIFICE

CHRONIC aortic endocarditis may be divided into two classes: (*a*) cases secondary to infectious endocarditis, and (*b*) cases due to arteriosclerotic processes. Calcareous change, which is nature's method of repairing weak structures, may occur in either, but is much more marked in the latter and in those cases in which the valvular disease has extended downward from the aorta. There is, however, another type of the sclerotic variety which is met with in middle life, which is secondary to syphilitic aortitis, is productive of valvular insufficiency, and is less prone to calcareous changes.

Fisher[1] calls attention to two distinct types of aortic disease: one of fatty degeneration with subsequent deposition of calcium salts, and one in which areas of grayish instead of yellowish thickening are found, the summits of which may be streaked with white or yellow, and which are localized to certain parts of the arterial wall.

AORTIC OBSTRUCTION

Occurrence and Pathogenesis.—Aortic obstruction is sometimes a congenital lesion, but generally it results from infective endocarditis. It may also be caused by arteriosclerotic processes. In its pure form it is a distinctly rare variety of valvular lesion. Syphilis, so often the cause of aortic insufficiency, causes obstruction less often, since the aortitis which this disease produces is generally most marked about $1\frac{1}{2}$ inches above the valves, and hence is more apt to produce dilatation and contractive shortening than actual obstruction. (See Fig. 71.) When aortic obstruction results from rheumatic fever, the mitral valve is generally involved also. The fact that this combination is so much commoner in men than in women would indicate that there is some other factor,

[1] Fisher: Hospital, Mar. 9, 1907, p. 406.

possibly strain, concerned. Allbutt states that the combined lesion is commoner in women who have had laborious occupations. Chorea as a cause of aortic obstruction is not frequent. Gowers[1] in 250 cases of chorea reported only three cases of aortic disease, only one of which was obstruction.

Morbid Anatomy.—The morbid anatomy of this condition varies considerably. Vegetations, fusion of the leaflets, infiltration, and stiffening or actual calcification may occur. At other times the cause of the obstruction is found in a mediastinal neoplasm or aneurism. Although at first sight the character of this lesion would seem to be one of exceptional severity, yet as a matter of fact its subjects often live a long time. Allbutt[2] states that under favorable circumstances life may continue until the aortic orifice—which measures 20 mm. at birth, 60 mm. in adult life, and 68 to 70 mm. in advanced years—is reduced to the size of a crow-quill or less. He quotes Bradbury's case, in which "the chink by which the blood found access to the aorta was only discovered on the closest search after death." Inasmuch as many cases are prolonged in duration and progressive in character, great hypertrophy of the ventricle is often found. It is in this variety of valvular lesion that the so-called "concentric hypertrophy" is most nearly approximated. Practically, however, some degree of dilatation is always associated.

Rarely a double obstruction is found, one at the aortic ring itself, and one beneath it, due to sclerosis of the tissue between the septum and the anterior mitral leaflet.

Coarction of the aorta consists of a narrowing of the vessel at that portion which extends from the subclavian artery to the ductus arteriosus. This part of the aorta carries before birth only part of its full quota of blood, and is hence small. After birth, when the side-track path of the ductus arteriosus is occluded, it assumes its full function and enlarges. Two types of coarction

[1] Gowers: Diseases of the Nervous System, 1892, p. 36.
[2] Allbutt: System of Medicine, 1898, vol. vi, p. 908.

have been described: (a) Infantile, consisting of a diffuse narrowing of the isthmus, developmental in origin. These cases die early. (b) Adult, consisting of an abrupt cord-like obstruction near the end of the ductus arteriosus. (See Fig. 83.)

Pathologic Physiology.—Owing to the obstruction to ventricular outflow blood-pressure is very greatly increased in the left ventricle, and this chamber empties itself much more slowly and gradually than normal. Left ventricular systole may consume from 5 to 50 per cent. more than the normal time, and blood-pressure in this chamber may even rise to twice the normal. Such

Fig. 16.—Mitral Stenosis.

L. F., male, white, aged thirty-five years. (Philadelphia Hospital. vol. xxiii, p. 1. Physician: Dr. F. P. Henry. Pathologist: Dr. Karsner.)

Clinical Notes: At one time *chorea;* some time after, while lifting a heavy weight, he felt something give way in the chest, and has been unable to work since. He is an intelligent mechanic, who has been under observation in this hospital for several years. *Symptoms:* Cyanosis, dyspnea, edema, arrhythmia (extrasystolic), tachycardia, pulsating liver, jugular veins, etc. Signs of double mitral and tricuspid lesion. *Died* gradually with symptoms of pneumonia.

Pathologic Diagnosis: Cloudy swelling of heart, with double-sized *dilatation*. *Mitral stenosis;* tricuspid insufficiency. Chronic congestion of lungs; hypostatic pneumonia of right; beginning gangrene of left. Cyanotic induration of kidneys; arteriosclerosis; chronic congestion with fatty degeneration of liver, also slight perilobular fibrosis, etc.

Pericardium: smooth and glistening, contains 150 c.c. of serous fluid.

Heart: is large, soft and flabby; weighs 580 gm. Epicardium shows a few areas of thickening about the apex. The muscle cuts with ease, and shows a light brown, slightly striated, bleeding, and friable surface. Left ventricular wall measures 11 mm. Aortic orifice, 6.5 cm., and shows moderate general thickening of the valve leaflets, and slight sclerosis of the sinus of Valsalva. *Mitral orifice was not incised; its leaflets are enormously thickened and contracted, showing at the right junction slight calcification; the whole presenting the appearance of the funnel-shaped buttonhole mitral. The chordæ tendineæ are enormously thickened, retracted and adherent, and are attached to papillary muscles which are much elongated and have sclerotic tips. The fibrosis of the anterior mitral leaflet extends forward along the septum, below the bases of the aortic valves, producing a thickening which extends transversely through the bundle of His. The ventricular cavity is enlarged,* contains chicken-fat clot, and well shows flattening of the columnæ carneæ. Right ventricular wall, 4 mm. Auriculo-ventricular orifice measures 15 cm.; shows leaflets which are moderately thickened along the free edge. Chordæ tendineæ thickened and retracted. Pulmonary orifice 9 cm.; shows general thickening of the valves and sclerosis of the sinuses. *Pulmonary artery* shows slight plaque-like sclerosis. Endocardium generally normal. Coronary artery moderately sclerosed.

(For *several years* previous to this patient's death the author had from time to time opportunities of studying the heart by means of the cardiosphygmograph. Very marked arrhythmia was always present and consisted of the type which Mackenzie describes as "*nodal rhythm,*" the "*pulsus irregularis perpetuus*" of Hering, but which, according to more recent investigations, is probably due to auricular fibrillation. This is of especial interest in view of the *extensive fibrosis in the region of the auriculo-ventricular bundle.*)
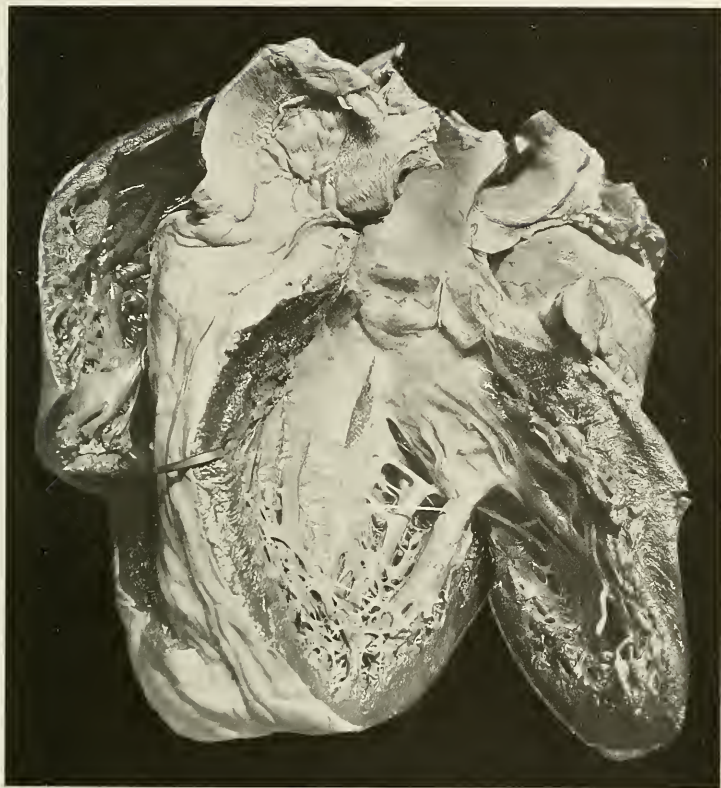
FIG. 16.

a state of affairs naturally causes a stasis and an increased pressure in the left auricle and in the pulmonary circulation, so that hypertrophy of the left ventricle and auricle, and in time of the right heart, occurs.

Up to a certain point the tendency of the left ventricle to hypertrophy is prevented by the prolongation of the presphygmic period,[1] a fact which gives the ventricle a longer time in which to empty itself. But since this prolongation of the presphygmic period s only limited, sooner or later hypertrophy must occur, owing to the increased demand for work. When dilatation of the left ventricle appears, a relative mitral insufficiency is established, which in turn and in time leads to pulmonary congestion, and to dilatation of the right heart.

Clinical Considerations.—The frequency with which this lesion is tabulated in some statistics is due to the fact that they were taken from clinical and not from autopsy records. A systolic murmur over the aortic area, especially in advanced years, is very common, and results, as a rule, from calcification, stiffening, slight roughening of the orifice, or dilatation of the aorta. Such conditions should, of course, not be considered an "obstruction." (See Fig 5.) At the Philadelphia General Hospital among 8,640 autopsies there were 42 cases of aortic obstruction (0.47 per cent.). Among 100 autopsies in Boston, Jackson[2] found 5 cases, one well marked. Aortic obstruction occurred in 5 per cent. of 1,781 cases of heart disease at the Johns Hopkins Hospital,[3] and in 2.73 per cent. of Romberg's cases.

When any considerable degree of obstruction exists, it is usually associated with insufficiency. Aortic disease occurs with especial frequency in the American negroes, a fact which is doubtless due to the prevalence of syphilis among them.

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[1] Gad and Luederitz: Zeitschrift f. klin. Medizin, xx, p. 374.

[2] Jackson: Boston Med. and Surg. Jour., 1896, p. 124.

[3] Hirschfelder: Diseases of the Heart and Aorta, 1910, p. 382.

AORTIC INSUFFICIENCY

Pathologic Anatomy and Occurrence.—Incompetence of the aortic valves generally results from disease of the leaflets, although leakage from dilatation of the aorta is occasionally accountable for the condition. Fibrosis, which generally acts by thickening, stiffening, retraction, or uneven contraction of the cusps, is generally responsible for the lesion. Such changes are often associated with disease of the root of the aorta, and hence the coronary arteries. With advancing years the aortic leaflets increasingly show the signs of wear and tear by a thickening, and curling, so that the margins fail to overlap. Endocarditic vegetations, ulcerations, and perforations of variable shape, size, and consistency are also responsible for a certain number of instances, but when such is the case the incompetency is apt to be associated with obstruction. Pure isolated aortic insufficiency is generally syphilitic or arteriosclerotic in origin. It is rare in children, and relatively frequent in men of laborious occupations, especially after forty years of age, and among syphilitics. It more commonly follows pneumococcus and gonococcus endocarditis than that which occurs in rheumatic fever and chorea. Occasionally aortic insufficiency is produced very early in certain cases of severe infective endocarditis in which there has been a rapid ulcerative destruction of the leaflets, but generally its production occurs slowly and insidiously. Among the rarer causes of aortic insufficiency valvular rupture resulting from strain or trauma, and congenital malformation of the cusps, may be mentioned.

In addition to the foregoing changes the following are generally seen: Thickening or atrophy of the endocardium; thickening of the free margins of the valves; atrophy of the trabecular muscles with connective-tissue infiltration; hypertrophy and dilatation of the ventricular muscle; also minute warty vegetations, the result of recent infection. The thickening of the free valvular margins is constant in aortic insufficiency, at times cylindrical, at

others irregular in shape. One, two, or all of the leaflets may be involved. The right cusp suffers most frequently and extensively. The valve flaps may be normal in size or even larger. Trabecular atrophy is most marked in the left wall of the ventricle near the apex. Wasting and flattening of the medial papillary muscle is common, as is also localized fibrosis of the subendocardial muscle, chiefly in the outer wall.

Zahn[1] has described as anatomically diagnostic of aortic insufficiency, (a) localized thickening of the interventricular septum, and (b) parallel, bow-shaped lines of varying thickness, composed of connective tissue, running at right angles to the cardiac axis and parallel to the aortic leaflets, on the endocardium of the ventricular septum. He attributes their formation to the constant downward pressure of the regurgitating blood, although he admits that the elasticity and contraction of the heart muscle might play an etiologically contributing rôle.

Lately Schminke[2] has reported an exaggeration of this process in which the redundant endocardial folds both on the septum and on the ventricular wall form small pockets—actual sacculations which are reproductions in miniature of the valves themselves. He believes that these pockets indicate a functionally compensating action on the part of the endocardium, through the agency of which the regurgitation of blood is diminished. He attributes their genesis to a process similar to that by means of which the semilunar valves develop in the fetal heart.

(Before the truncus arteriosus divides, four folds of gelatinous tissue covered by endocardium are formed, two of which, on division of the truncus arteriosus into the aorta and the pulmonary artery, are cut in half, so that each vessel gets three folds which subsequently take on the form of pockets, a metamorphosis in which the mechanical action of the blood-stream probably plays a rôle.)

[1] Zahn: Verhandlung. d. Kongr. f. inn. Med., 1895, p. 351.
[2] Schminke: Virchow's Archives, 1908, cxcii, p. 50.
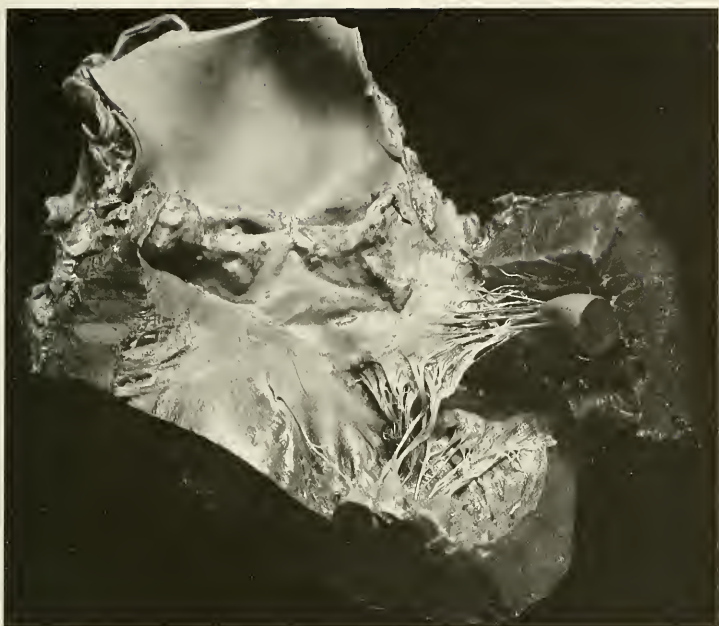
FIG. 17.—SCLEROTIC ENDOCARDITIS.

L. B., male, Italian, aged seventy-seven years. (Philadelphia Hospital vol. xxiv, p. 97. Physician: Dr. A. A. Eshner. Pathologist: Dr. H. T. Karsner.)

CLINICAL NOTES: Patient was admitted in a delirious condition. The heart is enlarged and its sounds are weak. No distinct murmurs are heard. The urine is albuminous. Hemoglobin, 68 per cent.; erythrocytes, 5,200,000. *Death* occurred gradually, preceded by an extensive and a generalized purpuric cutaneous erruption.

PATHOLOGIC DIAGNOSIS: Emphysema, hypostatic pneumonia, chronic interstitial myocarditis, *sclerotic endocarditis* of all the valves, chronic interstitial nephritis, etc.

HEART: Weighs 360 gm. The left ventricle measures 13 mm. The mitral orifice 11 cm. Its leaflets and chordæ tendineæ show slight general thickening and retraction. The papillary muscles are fibrosed. *The aortic orifice measures 7.5 cm. Its leaflets are thickened and at their bases slightly calcified. The sinus of Valsalva is sclerotic, this change involving the coronary orifices.* The right ventricular wall measures 6 mm., and the tricuspid orifice 9 cm., its leaflets being thickened. The pulmonic orifice measures 8.5 cm.; its leaflets are thickened, as is also the ventricular endocardium. The coronary arteries are slightly sclerotic.

This specimen illustrates the type of case in which the disease of the aortic leaflets is the primary and the main lesion, the aorta itself being relatively uninvolved. (Compare with Figs. 52 and 53.)

Experimental *section of the aortic valves* is followed almost at once by a fall of the diastolic pressure, by dilatation of the left ventricle, and sooner or later by the establishment of a mitral insufficiency. In man the occurrence of the latter has been regarded as beneficial, on the assumption that the leak acts as a safety-valve, just as does tricuspid dilatation in the right heart during muscular strain.[1]

Some unusual and curious aortic cases have been recorded. Thus, Tegeler[2] reported a case in which a revolver bullet was

[1] Taylor: Brit. Med. Jour., June 23, 1906.
[2] Tegeler: Münch. med. Woch., 1909, No. 34, p. 1740.

Fig. 18.—Chronic Mural and Aortic Endocarditis.

O. G., male, white. (Pennsylvania [Hospital. Autopsy: 1133. Physician: Dr. Newlin. Pathologist: Dr. Krumbhaar.)

Clinical Notes: Denies syphilis. *Gonorrhea* fifteen years ago, followed three months later by severe arthritis. Complains: Abdominal pain, constipation, headache, cough with slight expectoration, pain after food, eructations, orthopnea, edema.

Heart: Second space 3.5 cm. to right of mid-sternal line; fifth space 12.5 cm. to left of mid-sternal line. Action is regular. Sounds weak and soft. Distinct double apical murmur transmitted to axilla and base, loud at the aortic area. Water-hammer pulse. Blood-pressure: 135 mm.; diastolic 82 mm. (Stanton). Urine: Albumin and casts. *Death:* Gradual with delirium and coma.

Pathologic Diagnosis: *Chronic mural and aortic endocarditis* with *incompetency*. General arteriosclerosis, *cardiac hypertrophy and dilatation.* Chronic diffuse nephritis, etc.

Pericardium: Contains 50 c.c. slightly turbid fluid containing flakes.

Heart: Enormously *dilated* (15 x 14 x 9 cm.). Weighs 600 gm. Large milk spot on anterior surface of right ventricle, and a few small ones posteriorly. Over the auricular surface numerous minute reddish points. Muscle of the left ventricle light red streaked with yellow, but the right ventricle is pale and yellow. Currant-jelly clot in right side of heart and in auricular appendage. Right auriculo-ventricular valves normal. Muscle 6 to 8 mm. Left auricle and ventricle also currant-jelly clots. *Mitral valve is not much thickened, but is shrunken and apparently incompetent. Aortic valves are diffusely thickened, and the aorta shows general sclerosis. The endocardium, especially of the septum, shows peculiar raised white streaks of an irregular padding which measure 2 mm. in diameter and project from the surface 2 mm. Just below the aortic valves there is a diffuse thickening of the endocardium, which extends into the aortic valve for some distance, and also into the mitral leaflets. Left ventricular muscle 14 to 18 mm.;* normal in color and firm. Its cavity shows some dilatation. *The coronary arteries are sclerotic near their origin,* but the small branches are thin and delicate. Valves: Tricuspid 12; pulmonary 8; aortic 9; mitral 11 cm. in circumference.

Microscopic Examination: Immediately beneath the endocardium the muscle-fibers are much swollen, granulated and vacuolated, with ragged edges. They have lost their striæ. Nuclei are large, and in the longitudinally cut fibers vacuolization is found to be most marked about the nuclei. This process is well marked in the papillary muscles, their endocardial covering being thickened. There is a slight diffuse increase of delicate fibrous tissue. In some places this is sufficiently marked to produce atrophy and degeneration of the muscle-fibers.

Fig. 18.

unexpectedly found encysted in an aortic cusp, in a man who was accidentally killed by other causes. In Jacobi's case,[1] which appeared to be traumatic in origin, the heart murmurs could be heard across the room. The question of *foreign bodies in the heart* has been studied by Zesas,[2] who collected 118 cases.

Pathologic Physiology.—Owing to the increased amount of blood which the left ventricle is called upon to handle, hypertrophy and dilatation occur. In favorable cases when the nutrient supply of the ventricle is sufficient, this process goes on for a long time. In such events the enormous *cor bovis* is produced, an enlargement greater than is seen in any other form of valvular disease. When the hypertrophic growth exceeds the nutritive supply, however, as is sooner or later bound to occur, degenerative changes followed by dilatation and signs of insufficiency occur. Or it may be that before these changes are brought about, the mitral valve, owing to constant overstrain, by virtue of either actual damage to its leaflets or dilatation of its sphincter, becomes markedly insufficient, and thus a pulmonary congestion is brought about. The marks of wear and tear upon the left-sided valves, and upon the whole arterial system, in this form of valvular disease are very pronounced. The incessant pounding of the hypertrophic ventricle, the high systolic and low diastolic pressure, produce a very intermittent blood-supply, which of course affects the coronary arteries as well as those of the whole arterial system. If one-third or one-fourth of the systolic output regurgitates, marked hypertrophy and dilatation will of course occur; but if the aortic lesion is slight, so that only a few cubic centimeters of blood flow backward, although a diastolic murmur may be heard, yet enlargement of the heart may not be sufficient to be clinically demonstrable (Krehl).

The experiments of Henderson, Stewart,[3] and Moritz indicate that much less blood regurgitates in aortic insufficiency than has

[1] Jacobi: New York Med. Jour., Aug. 9, 1902.
[2] Zesas: Fortschritte in. d. Medizin, 1910, xxviii, p. 649.
[3] Henderson: Archives of Internal Medicine, Jan., 1908.

FIG. 19.—AORTIC OBSTRUCTION, SEEN FROM ABOVE.

The leaflets are fused together, thickened, and indurated. They are covered with small vegetations.

hitherto been supposed. This is owing to an increased tonicity which the left ventricle assumes. The marked fluctuations of blood-pressure which occur in these cases seem to be due to a reflex lowering of the diastolic pressure. This is borne out by the well-known clinical fact that diastolic pressure often ranges between 40 and 60 mm. Hg, even where compensation is fairly well maintained, while the systolic pressure is often as high as 180 mm. The amount of regurgitation depends upon the severity of the lesion and the efficiency of compensation in the myocardium, especially of the left ventricle and of the left auricle.

Until quite recently it was generally believed that aortic insufficiency was due to the same causes as those which produce an obstruction or sclerotic change. Although this is no doubt true, yet recent investigations point very strongly toward the fact that a large number, if not the majority, of cases of isolated aortic insufficiency are the result of syphilis. The association of this lesion with locomotor ataxia has long been noted,[1] and recently it has been shown that a very large proportion of cases of aortic insufficiency give a positive Wassermann reaction,[2] while mitral cases do so only exceptionally. The spirocheta pallida has been demonstrated in these lesions.[3]

The possibility of a relative or *functional aortic insufficiency* has been much discussed, and seems to have been definitely established by having been experimentally produced by Thayer and MacCallum.[4] But certainly the vast majority of cases of this lesion seen in practice result from actual valvular damage— thickening, shrinking, perforation, stiffening, roughening, or calcification of the aortic cusps. It can be easily understood that where such changes as those just mentioned are present,

[1] Babinski: Soc. Méd. des Hôpit., Paris, 1901, Nov. 14 and 21. Strümpell: Deut. med. Woch., 1907, No. 47. Schütze: Deut. Zeit. f. Chir., 1908, 1–5, etc.

[2] Danielopolu: Bull. Soc. Biolog., Paris, May 30, 1908. Collins and Sachs: Amer. Jour. Med. Sci., Sept. 1909. Débove and Trémolières: Jour. Med. Français, April, 1910. Longcope: Jour. Am. Med. Assoc., 1909. Pasaschivescu: Thèse de Bucarest, 1910.

[3] Wright and Richardson: Boston Med. and Surg. Jour., April 29, 1909.

[4] Thayer and MacCallum: Amer. Jour. Med. Sci., Feb., 1907.

both obstruction and insufficiency are apt to result, and such is generally the case—a pure insufficiency or obstruction being the exception.

Clinical Considerations.—Aortic insufficiency may exist without an audible murmur, and even when such is present it is apt to be low-pitched and difficult to hear. Jackson found that this was the most frequently overlooked valvular lesion in 100 autopsies. Animal experimentation has further corroborated the foregoing statements. In advanced life relative aortic insufficiency is favored by the fact that both the diameter and the length of the aorta increase with time, while its elasticity diminishes.[1]

[1] Scheel: Virchow's Archiv, cxci, 1908.

IV. DISEASES OF THE MITRAL ORIFICE

MITRAL OBSTRUCTION

Varieties.—From an *etiologic standpoint* there are three varieties of this lesion: (*a*) infectious; (*b*) arteriosclerotic; (*c*) congenital; the first-named being probably the commonest. Hensen has reported mitral stenosis as the result of pressure from a thoracic aneurism. Morgagni reported one due to the pressure of a calcified pericardium. *A functional form of mitral stenosis*, supposedly due to nervous influences, occurring chiefly in neuropaths and chlorotics, as the result of orificial constriction or retroversion of the leaflets from the regurgitating blood of an aortic insufficiency, has been described especially in the French literature.[1] Its existence rests upon purely hypothetic grounds, and is very questionable.

From the *anatomic standpoint* four varieties are recognized: (*a*) buttonhole; (*b*) funnel-shaped; (*c*) vegetative; (*d*) cystic (due to valvular aneurism).[2]

The mitral orifice in men averages 110.37 mm., in women 92.68 mm. in circumference. The mitral and tricuspid valves show the greatest difference in size when the sexes are compared, a fact which probably has some bearing on the preponderance of stenosis of these orifices in women.

It has been shown that the large, freely movable anterior mitral leaflet has a somewhat different function from the small, relatively fixed, posterior leaflet, in that the former, in addition to preventing regurgitation into the auricle during ventricular systole, actually forms, together with the interventricular septum, a channel which helps to conduct the ventricular contents into

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[1] Bard: Semaine Méd., 1906, No. 20. Lepine: Provence Médic., xx, No. 2. Ceeone: Riforma Medic., July 27, 1908.

[2] Cruveilhier: Anat. Path., ii, 1852.
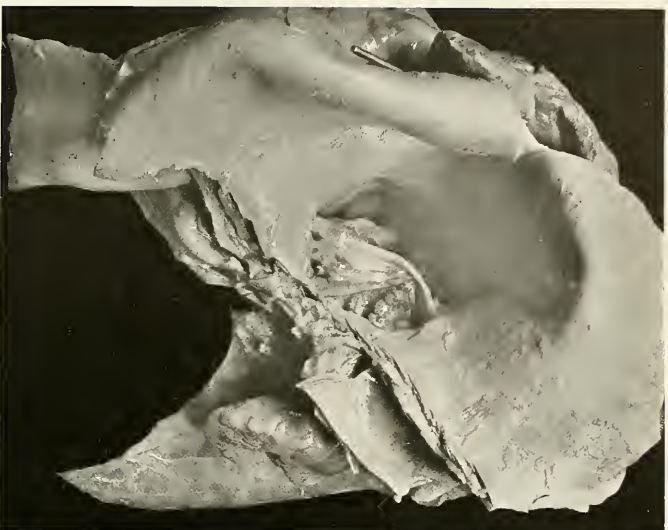
Fig. 20A.—Aortic Obstruction, Seen from Above.

An extreme grade of the lesion. The orifice is entirely closed as the result of fusion and vegetation of the leaflets. The tissues are much indurated and thickened and an opening can be made between them only by exerting a considerable pressure. The aorta shows well-marked diffuse sclerosis. (Specimen from the Philadelphia Hospital.)

Fig. 20B.—Aortic Obstruction from Above.

The margins of the leaflets are fused together, thickened and calcified, reducing the orifice to about one-third of its normal caliber. The mitral and tricuspid orifices are also sclerosed and contracted.

5

the aorta [1] (the "Stromrinne" [flume] of Oesterreich [2]). It has thus a double function, and pathologic alterations in its structure have a double result. In this connection Beitzler [3] considers the white spots frequently to be found on the ventricular surface of the anterior mitral leaflet as mechanical and not inflammatory in origin, due to conditions similar to those which are active in the production of aortic sclerosis. Looked at, then, from the standpoint of physiology, this surface of the anterior leaflet is really a part of the aorta. The fact that this leaflet is so much oftener diseased than the others has also been explained as due to greater tension when closed (Sibson), a smaller line of contact during closure, greater tendinous traction, greater vascularity,— favoring embolic processes. It should also be borne in mind that the anatomic relationship of the mitral, tricuspid, and aortic valves is a very intimate one. (See Figs. 7 and 8.)

Pathologic Anatomy.—Mitral stenosis [4] may or may not begin as an insufficiency, which, through gradual adhesion of the leaflets and contraction of the surrounding tissues, ends as a combined lesion, sometimes passing through a stage of firm obstruction. When the free edges of the leaflets are chiefly involved, the well-known *funnel-shaped* orifice, which is generally seen in early life, results. (See Figs. 16 and 22.) When mechanical pressure factors have existed, as in the cases occurring in chronic nephritis, the leaflets are less affected, and the lesion consists more of a thickening, hardening, shortening, and sometimes a calcification of the papillary muscles and chordæ tendineæ. "The insertions of the chordæ tendineæ are spread out over the greater part of the lower surface of the leaflets, and when there is long-continued, high, intracardiac pressure, the whole valve becomes very much thickened, and there is a great increase in the fibrous tissue, which eventually leads to the puckering or contraction of the segments, and the

[1] Arch. f. exp. Path. u. Pharm., 1907, lvii, 57.

[2] Virchow's Arch., lxi, pp. 180, 196.

[3] Virchow's Arch., 1901, lxi, 343.

[4] Heitz and Sézary: Arch. de Mal. du Cœur, Dec. 1, 1908.

diaphragmatic or *buttonhole variety* is produced."[1]   (See Fig. 24.)
Some writers—Hayden, Sanson,[2] Hilton, and Fagge—have held
that the funnel shape is almost exclusively that of youth, and the
buttonhole form that of adult life.   Barr suggests that it is largely
a question of the duration of the lesion, and that long-standing
cases, with marked infiltration, sclerosis, and contraction (and
these are the conditions which obtain later in life), develop the
buttonhole shape.

" In some cases the mitral cusps are so thickened and contracted
that they merely form a transverse septum with a narrow slit
between auricle and ventricle.   In such cases the chordæ tendineæ
are frequently thickened and matted together, and the papillary
muscles in such a fibroid condition that it would seem impossible
for a first sound to be generated by the mitral valve."

A congenital form is frequently discussed, especially in the
French literature.   It is described as often of the funnel-shaped
type, produced by fusion of the leaflets, which are said to resemble
other congenital lesions n that they present no signs of inflamma-
tory changes—thickening, contraction, etc.   It is sometimes asso-
ciated with other developmental anomalies, such as hare-lip.
Occasionally it occurs together with infantilism, myxedema, etc.[3]
Other observers consider that these lesions result from a fetal
endocarditis.   The symptoms in these cases appear between the
seventh and fourteenth years, the period in which, despite rapid
bodily growth, the heart remains almost at a standstill.

According to Bizot and Beneke, the heart, which is perfectly formed by the
seventh week after conception, doubles its size between the time of birth and the
age of twenty-four months, and again between three and seven years.   It re-
mains almost stationary from seven to fifteen years, and again increases one-
third of its size between fifteen and twenty years, at which time normal growth
practically ends.[4]

[1] J. Barr: Lancet, Dec. 19, 1908, p. 1789.
[2] Sanson (Allbutt's System): In children one "buttonhole" is seen to eight funnels, where-
as in adults there is one funnel to twenty-five "buttonholes."
[3] Kippel and Chabrol: Rev. de Méd., 1910, p. 153.
[4] Quoted Pawlinow: "Kongenitale Mitral Stenose," Berlin, 1909, p. 6.

Quénus[1] states that the mitral valves are developed in the second and third months of fetal life, existing at first as muscle-fibers which at the beginning of the fourth month are transformed into connective tissue. It is in this stage of embryonic life that congenital lesions would be produced.

Pawlinow states that in congenital mitral stenosis neither the right ventricle nor left auricle hypertrophy, owing presumably to nutritional defect. The leaflets themselves are thinner, weaker, more delicate, and are more easily torn than normal ones. He believes that the cases of mitral stenosis which Pitt[2] describes as so frequently associated with chronic nephritis are cases of congenital mitral stenosis, and that this congenital form predisposes to infections. The heart is smaller, but the patient's life longer, than in the acquired lesions, for despite the fact that many cases develop pulmonary tuberculosis, the latter tends to run a prolonged course. This association of mitral stenosis and pulmonary tuberculosis was explained by Potain as due to toxemia.

The belief that mitral stenosis is often a result of acquired or hereditary pulmonary tuberculosis, was first enunciated by Tripier,[3] and notably elaborated by Potain[4] and Teissier.[5] A full discussion of this hypothesis would lead too far. Suffice it to say that this view that mitral stenosis may be caused by the toxin of the tubercle bacillus is not generally accepted. Hereditary syphilis has also been described as a cause.[6]

The normal auricular capacity ranges between 40 and 70 cm. (average 55 cm.). In mitral stenosis these figures may be greatly increased. In one case reported by Briquet[7] the enormous proportions of 650 cm. were reached—practically equal to the size of a whole normal heart. Auricular hypertrophy is insignificant compared to what may occur in the ventricle, nevertheless an increase to the thickness of 3 cm. has been observed.[8] Atrophy

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[1] Quénus: Thèse de Paris, 1833, p. 42.

[2] Pitt, at Guy's Hospital, found that mitral stenosis occurred three times as often in association with renal sclerosis as in other diseases, and that two-thirds of the cases occur in women.

[3] Tripier: Arch. de Méd. Exper., 1888.

[4] Potain: Jour. de Méd. et de Chir. Prat., 1891.

[5] Teissier: Thèse de Paris, 1894. Sears (St. Paul Med. Jour., March, 1907) found well-marked tuberculosis in 11 or 22 per cent. of the Boston City Hospital cases. A number of other cases showed chronic pleuritis, which, if counted as tuberculous lesions, would raise the percentage to 40. Crawford in 112 autopsies found pleuritis 48 times, but definite tuberculosis only twice.

[6] Labadie, Lagrave, and Deguy: Jour. des Prat., July, 1899.

[7] Briquet: Thèse de Paris, 1890, case xix.

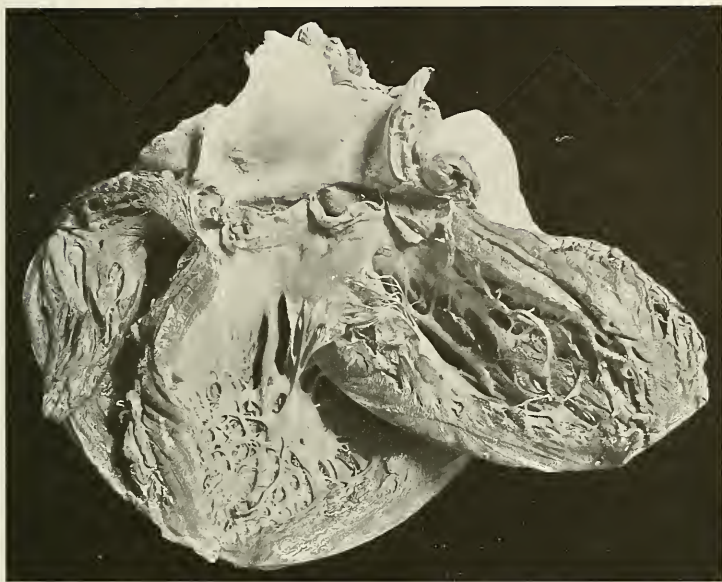[8] Bourdel: Soc. Anat. Paris, 1880. Samways: Thèse de Paris, 1896.

FIG. 21.—CHRONIC AORTIC AND MITRAL ENDOCARDITIS, WITH HYPERTROPHY AND DILATATION OF THE LEFT VENTRICLE.

The aortic valves are thickened and retracted. The aorta above them shows well-marked sclerotic changes involving the mouth of the right coronary artery. The mitral valve is thickened, retracted, and sclerotic. The predominant lesion in each instance is insufficiency. (Specimen from the German Hospital, Philadelphia.)

of the auricular muscle is by no means rare, and may be of such extreme degree that the muscular tissue may completely disappear, leaving only a fibrous sac.[1] When the auricle is thus greatly distended, its functional capacity ceases, as is shown by the disappearance of the auricular wave in the jugular (Mackenzie), in the esophogram (Joachim), and in the volume curve (Hirschfelder). Occasionally enormous dilatation is met with, as in Müller's case, in which the left auricle was larger than a child's head, and the heart weighed 620 gm., the patient's bodily weight being only 65 Kg. (normal relations: heart, 297 gm. to body of 60 or 70 Kg.).

According to Witwicki,[2] the left auricle is the most distensible of all the heart chambers, and Samuelson[3] has stated that occlusion of the left coronary artery produces a flaccid dilatation of the left auricular wall. Although these facts may be correct, the left auricle is, owing to its anatomic relations, much less likely than the right to expand, since such an occurrence can take place in but one direction, viz., upward. Owen and Fenton have reported a left auricle with a capacity of 900 c.c.,[4] and Minkowski[5] has recorded a dilated heart which contained 4 liters of blood, nearly three of which were found in the left auricle. In such cases the auricular wall exists as a mere membranous sack, no thicker than a visiting card (Sansom), and resembles a greatly distended bladder. Such distention by dilation of, and upward pressure on, the left pulmonary artery may cause left recurrent laryngeal paralysis by compression of this nerve between the last named vessel and the aortic arch. Ten such cases with autopsy reports and a considerably larger number of clinical observations are now on record. In some of these cases direct pressure of the

[1] Müller: Zeit. f. klin. Med., 1905, lvi, p. 520.

[2] Witwicki: Zeit. f. kl. Med., xxvii, 1895, p. 321.

[3] Samuelson: Ibid., vol. ii.

[4] Fetterolf and Norris: "The Anatomic Explanation of Paralysis of the Recurrent Laryngeal Nerve Found in Certain Cases of Mitral Stenosis." Trans. Coll. Physicians of Philadelphia, 1911, Am. Jour. Med. Sc., 1911.

[5] Owen and Fenton: Trans. Clin. Soc. London, May 24, 1901.

left auricle upon the aorta has been described, but as has been shown by Fetterolf and myself such a state of affairs is anatomically impossible.[1] Right recurrent paralysis has also been described, it being assumed in explanation, and without post-mortem substantiation, that the brachiocephalic and the subclavian arteries had undergone displacement.

It was formerly taught that mitral stenosis is practically always *associated with insufficiency.* This has been vigorously contradicted, and much discussion has been aroused. Romberg found only two cases of pure stenosis among 670 heart cases. Krehl considers it very rare, and some clinicians deny its existence altogether. Hampeln,[2] on the other hand, finds pure obstruction in from 10 to 20 per cent. of all his mitral cases, and Schabert[3] states that at least half of all the mitral lesions at the Stadtkrankenhaus at Riga are pure stenosis. There can be no question that in a good many cases the stenotic is the serious and evident, and the insufficiency the slight and inconsequential lesion. Personally, although I have seen quite a number of cases of isolated obstruction, yet it is my belief that the lesion is much more commonly a mixed one.

Etiology.—The great majority of cases of mitral stenosis, especially those of early life, owe their existence to an antecedent *rheumatic infection.* Following this in frequency come chorea, arteriosclerosis, and infectious processes of different kinds, including syphilis. *Chronic interstitial nephritis* is also not infrequently associated with mitral stenosis.

Goodhart in 192 cases of this form of renal disease found the last-named valvular lesion in about 25 per cent., and Pitt states that mitral stenosis is three times as common in patients with Bright's disease as in those not so afflicted. Although these facts are doubtless correct, it must not be forgotten that in these cases the valvular disease is simply a part of a general arteriosclerosis, in which such extreme degrees of mitral disease as are seen as the result of inflammatory lesions are distinctly the exception. They occur in individuals more advanced in life, present quite a different clinical picture, and play much less important a rôle in the production of death.

Occurrence.—Among 4,791 autopsies at Guy's Hospital, Samways[4] found 196 cases of mitral disease in which the orifice

[1] Minkowski: Münch. med. Woch., lvi, 1905, p. 182.
[2] Hampeln: Deut. med. Woch., 1908, p. 1301.
[3] Schabert: Deut. Arch. f. klin. Med., 1909, p. 117.
[4] Samways: Brit. Med. Jour., 1898, p. 361. (Among 8,610 autopsies at the Philadelphia Hospital there were 116 well-marked cases of mitral stenosis.)

measured less than $3\frac{1}{2}$ inches (admitted two fingers or less).
Minor grades of stenosis were therefore excluded. In 108 cases
the orifice measured $2\frac{1}{4}$ inches (admitted one finger) or over,
and in 85 cases measured less than $2\frac{1}{4}$ inches, three cases being
doubtful; 107 cases were in females, 89 in males. The average
age at the time of death among the former was 33.6 years; among
the latter, 43.6 years. In 32 cases tricuspid obstruction was
also present; generally this occurred in the severe cases. In a
large proportion of cases the aortic valve was also thickened,
but actual stenosis was seldom encountered. *Left auricular
hypertrophy* occurred in 44 of 77 severe cases, and in 21 of 96
moderate cases (in the first class in more than half, in the second
in less than one-quarter). *Left auricular dilatation* was marked
in 14 of 77 severe, slight in 6, the data being incomplete in 18
cases. *Right ventricular hypertrophy* appeared in 41 of 77 severe,
and 25 of 96 moderate cases. *Right ventricular dilatation* was
present in 40 out of 77 severe, and 27 of 96 moderate cases. The
left ventricle was generally normal or small, rarely enlarged.
Among 23 cases dying "surgical deaths," only 4 had dilated left
auricles. *Pericarditis* was present in nearly one-third of the cases,
and sudden death occurred in 7. Sixty per cent. of the cases
gave a history of rheumatic infection. Nineteen cases were ad-
vanced in life and gave no such history, showing that this lesion
may have a sclerotic as well as an infectious origin. Nearly all
statistics show that mitral obstruction, especially the form which
occurs in early life and results from an infectious valvulitis, is
very much more common in the female sex. Various explanations
have been offered, such as, for instance, that prolonged subacute
infections are more frequent in women, also that, owing to
lessened cardiac activity and intracardiac pressure, the mitral
valve makes less extensive excursions, and is hence more prone
to adhesive changes. Congenital structural differences have also
been suggested. It must be admitted, however, that none of
these explanations are satisfactory. Among 50 autopsies of

Fig. 22.—Mitral Stenosis.

Specimen showing mitral stenosis viewed from the ventricular side. The valvular endo-
cardium is thickened and has lost much of its flexibility; the chordæ tendineæ are thickened,
indurated, contracted, and more or less fused together. Small verrucose vegetations are seen
on the ventricular endocardium just to the left of the mitral valve.

mitral stenosis cases Sears found in 25 a mitral lesion only (19 admitted only one finger). In 7 other cases the mitral lesion was the principal one (2 fibrous pericarditis, 5 aortic disease). So that in 27 cases there was mitral disease alone, in 17 mitral and aortic, in 1 mitral and tricuspid, in 5 mitral, aortic, and tricuspid, in 4 fibrous pericarditis.

Pathologic Physiology.—The presence of mitral stenosis at first tends to produce left auricular hypertrophy, owing to obstruction to outflow offered by the constricted orifice. Hirschfelder[1] and Wolfsohn have shown that the first effect of mitral stenosis as indicated by the volume curve is to slow the inflow into the ventricles. "As the result of this the left auricle is more than usually full at the time of its systole, and forces an unusually large quantity of blood into the ventricle." The capability of the auricle to hypertrophy is limited, however, and great thickening of its walls is rarely seen. With continued overwork the chamber elongates, becomes cone-shaped, and, as nutrition fails, dilates. That this dilatation is not a conservative phenomenon, but an evidence of failing compensation, has been pointed out by Samways, who in 36 severe cases of mitral stenosis found hypertrophy in 26, whereas dilatation occurred in only 14, in 11 of which it was associated with hypertrophy. This process of dilatation manifests itself first in the auricular appendix, owing to the relatively unyielding structures by which the auricle proper is surrounded (the aorta, vertebræ, and esophagus behind, the other heart chambers in front, the diaphragm and liver below, and the aortic arch and pulmonary artery above). (See Figs. 45, 46, and 47.)

Thrombosis, either ante mortem or post mortem, of either of these chambers occurs frequently, owing to circulatory stagnation and roughening of the endocardium by vegetations. (See Fig. 9.) Such a state of affairs is a prolific source of emboli, and adds much to the weakness of the heart which is manifest during intercurrent infections, such as influenza, and which is often attributed to

[1] Hirschfelder and Wolfsohn: Johns Hopkins Hosp. Bulletin, xix, 1908.

FIG. 23.—MITRAL STENOSIS.

Two hearts illustrating mitral stenosis as seen from the auricular side. Both of them show contracted orifices with marked induration of the leaflets. The illustration on the right also exhibits small verrucose vegetations.

myocarditis (Huchard). Increased pressure leads to endocardial thickening in the auricle, and as compensation fails, to thickening and dilatation of the pulmonary artery. In time the right ventricle hypertrophies as the result of pulmonary stasis, and assumes a somewhat rectangular shape from enlargement of the conus. When this chamber dilates under continuous overstrain, tricuspid insufficiency occurs, which in turn leads to overdistention of the right auricle. This chamber in extreme cases becomes greatly thinned, stretched, and ceases to contract, becoming eventually a mere distended reservoir at the orifices of the venæ cavæ.

The question as to whether mitral stenosis can produce left ventricular hypertrophy has provoked much discussion, a good deal of which may be found in Dunbar's[1] article. He himself found hypertrophy and dilatation in cases with good compensation. Some observers state that atrophy is the commonest lesion, and attribute its existence to a lessened amount of blood which this chamber is called upon to handle. The existence of left ventricular hypertrophy, when present, has been explained as resulting from back pressure in the venous system, making it more difficult for the blood to pass from the arteries into the veins, and thus necessitating increased ventricular effort. An increased systemic venous pressure has been found by some observers, but is denied by others. Another reason for hypertrophy has been offered by Giuffré, namely, that diastolic filling is interfered with as a result of the mitral narrowing, and since diastole is now generally regarded as in part, at least, an active muscular action, an obstacle to it would lead to enlargement. A very excellent study of this subject has been made by Hirsch, who examined the hearts in ten cases by the Müllerian method, and found hypertrophy only when insufficiency of the mitral was the chief lesion. Schabert also found either an actual atrophy of the ventricle or at least no increase in pure obstruction. There seems to be little doubt that *left ventricular hypertrophy, when present, can generally be accounted for by other lesions, either within or without the heart.*

[1] Dunbar: Deut. Arch. f. klin. Med., 1892, p. 283.

Mitral obstruction may be produced *experimentally* either by introducing a distensible balloon through the auricular appendage, or by passing a suture or clamp around the auriculo-ventricular ring.[1]

"The immediate result is the lowering of the general arterial pressure and the great elevation of the pressure in the pulmonary arteries, the pulmonary veins, and the left auricle. The pressure in the systemic veins is little if at all elevated, unless there arises an insufficiency of the right ventricle, or with it a relative insufficiency of the tricuspid valve. The essential feature of the process, as indeed of all changes of blood-pressure due to any obstruction of the blood-stream from alterations of the heart, lies in the fact that the amount of blood in actual circulation is diminished, while the rest of the blood stagnates behind the obstruction."

In the human being the constrictive process occurs gradually, and thus a better chance for compensation is offered. The fall in the systemic pressure is counterbalanced by an increased arterial constriction, so that arterial tension is maintained at practically a normal level.

Clinical Considerations.—Owing to the serious and progressive character of mitral stenosis, and the fact that so many cases wreck individual existences early in life, Sir Lauder Brunton suggested some years ago that at some future time this lesion might be treated by surgical means. At present this is, of course, out of the question, but recent experience shows that this is by no means as chimerical a suggestion as it at first appeared to be. The heart is no longer surrounded by an invincible *noli me tangere*. Bernheim's experiments have shown that it is a good deal easier to convert a mitral obstruction into an insufficiency than to produce the former lesion.[2] Wounds of the heart are treated on the same principles as the wounds of other muscles, and with no small degree of success. Of some 160 cases of cardiac wounds surgically treated thus far, 69 were in the right ventricle, with 48 deaths (69.6 per cent.); 74 in the left ventricle, with 45 deaths (60.8

[1] MacCallum and McClure: Trans. Assoc. Am. Phys., 1906, p. 5.
[2] Bernheim: Bulletin Johns Hopkins Hospital, April, 1909.

per cent.); 5 in the left auricle, with 2 deaths (33.3 per cent.).[1]
Furthermore, Elsberg[2] has shown experimentally that the heart
in rabbits and dogs is capable of resisting an astonishing amount
of trauma, "even ligation of the entire left heart at the junction
of the lower and middle thirds of the ventricles, and amputation
through the ventricles below the ligature, may be followed by
recovery."

While mitral stenosis is generally and justly regarded as a
far more serious lesion than insufficiency, yet this question is
worthy of some little thought. Mitral stenosis is perhaps not so
rare a lesion as some of us think,[3] and the recent investigations
of Schabert are at least suggestive of the fact that some stenoses
may be the terminal stages of insufficiencies. The question as
to the preponderance of the lesion can to a certain extent be
determined by careful weighing of the fat- and blood-freed in-
dividual heart chambers, and by the water test; but, needless
to say, other conditions, such as the hypertension of nephritis,
must be carefully excluded before drawing definite conclusions.

The fact that mitral obstruction is not rarely associated with
congenital malformations naturally suggests a common cause,
such as syphilis, alcoholism, tuberculosis in the parents, etc.
Heitz and Lezary[4] have recently collected 15 cases in which, in
addition to mitral stenosis, such lesions as syndactylia, ectopic
testicles, harelip, sternal malformations, imbecility, were observed.
It is quite possible, however, that such cases are coincidences,
or the result of an intrauterine infection, since the symptoms of
mitral stenosis rarely manifest themselves before the twelfth
year (Poynton). A "mitral heredity" has been dwelt upon by
Hirtz.[5]

[1] Peck: Annals of Surgery, July, 1909.

[2] Elsberg: Jour. Exper. Med., 1899, p. 479.

[3] Cabot states that 25 out of 48 cases discovered at autopsy at the Massachusetts General
Hospital were overlooked clinically.

[4] Heitz and Lezary: Arch. d. Mal. du Cœur, 1908, i, p. 701.

[5] Hirtz: Presse Méd., Sept. 19, 1903.

Fig. 24.—Stenosis of the Aortic, Mitral, and Tricuspid Valves.

The aortic leaflets are fused together and the orifice is greatly reduced in caliber. The mitral orifice consists of a mere slit, of crescentic outline—buttonhole type. The tricuspid orifice is also contracted. (Specimen from the Philadelphia Hospital.)

MITRAL INSUFFICIENCY

Pathogenesis.—The mitral valves may fail to prevent backward leakage owing to organic disease or to atonicity of the muscular sphincter, upon the integrity of which the proper functionation of the valve so largely depends. This atonicity of the sphincter in turn may result from muscular degeneration or from purely functional causes. The conditions necessary to produce a functional lesion are diminished muscular tonicity and an overworked ventricle. When mitral insufficiency results from organic causes, it is not infrequently associated with some obstruction. The valves may be fused, retracted, puckered together with more or less induration of the leaflets or the surrounding structures. Insufficiency may also occur when the left ventricle enlarges to such an extent as to draw on the papillary muscles before the leaflets are in complete apposition. Actual ulcerations, perforations, or vegetations may also prevent sufficiency. In fact, Schabert's recent studies indicate that such lesions are the commonest cause of pure organic mitral insufficiency.

Occurrence.—Mitral insufficiency is the commonest of all valvular diseases, constituting about 25 per cent. of all such cases. Among 1,024 cases of valvular disease in applicants for life insurance Ashton found mitral stenosis 32, insufficiency 557, aortic obstruction 136 (?), insufficiency 47.[1] At the Edinburgh Infirmary out of 1,914 cases of valvular disease there were 585 cases of pure insufficiency, and 463 combined mitral lesions, 231 of which were mitral stenoses.[2] Among the 8,640 autopsies at the Philadelphia General Hospital there were 1,253 cases of chronic mitral endocarditis. Among these there was one aneurism (with rupture), one hematoma, and one case of supernumerary leaflets.

The great discrepancy between the frequency of the diagnosis of mitral insufficiency in clinical records, and in autopsy statistics, is to be explained by the fact that, accepting the statement of

[1] Ashton: Medical News, June 30, 1894.
[2] Gillespie: Edinburgh Hospital Reports, 1898, p. 31.

Virchow, it has been held to be impossible to test the functionation of this valve by hydrostatic methods, in the way in which the semilunar valves may be. Lately Schabert[1] has especially studied this question and found that such a test can be made with comparative satisfaction, celerity, and accuracy, and as a result three grades of insufficiency have been suggested. (The valves may also be tested with an air-bellows.[2])

The left auricle is cut up as far as the mitral insertion, and the flap reflected for inspection. The aorta is occluded by pinching, and through a cut in the ventricular wall a tube connected with running water is introduced into the ventricle. A source of error is admitted for hearts of greatly relaxed musculature,—anemia, sepsis, postmortem decomposition, etc.,—and also for cases in which thrombi are lodged between the leaflets. Similar conclusions, though based on a different technic, have been reached by Oesterreich and Bleicheroeder.[3]

Notwithstanding these tests, however, functional and even organic insufficiency is often overlooked at autopsy on account of rigor mortis of the heart muscle which prevents relaxation, and also on account of the redundancy of the valves.

Pathologic Anatomy.—The anatomic changes in mitral insufficiency consist of sclerotic, ulcerative, or vegetative alterations of the leaflets or chordæ tendineæ, with occasional perforation or rupture, and frequently with induration and shortening. The commonest sign of relative insufficiency consists of thickening of the free valvular margin with more or less contraction, the former being generally uniform. Inversion of the flaps is rare because the chordæ tendineæ are so attached as to leave a considerable margin between their insertions. When actual inversion does occur, it is generally on the anterior leaflet. On the posterior surface of the auricle, between the valve opening and the mouth of the pulmonary veins, we sometimes find the endocardium infiltrated and thickened, presenting an angular, ridgy, gelatinous appearance, with the convexity toward the pulmonary veins

[1] Schabert: Zentralb. f. Path. u. path. Anat., 1907, p. 33.
[2] Hamilton: Text Book of Path., 1889, p. 9.
[3] Oesterreich and Bleicheroeder: Virchow's Arch., vol. cli, p. 195, 1902, p. 159.

(Zahn). In the earlier stages the auricle is hypertrophied, and in advanced cases atrophied. The valvular leaflets are thickened and at times show aneurismal dilatation. (See Fig. 15.) The auricular surface of the anterior leaflet generally shows the most marked changes. The early evidences of rheumatic endocarditis consist of small nodules on the leaflets, and are of little importance of themselves. The later and serious changes result from extension of the inflammatory process to the chordæ tendineæ, which become thickened and shortened. "Rheumatic disease of the mitral valve is mainly a disease of the chordæ tendineæ" (Fisher). This process of contraction ultimately leads to stenosis and insufficiency.

Pathologic Physiology.—"In every variety of uncompensated valvular lesion, either an insufficiency or an obstruction, blood-pressure and systolic output fall on the distal, and rise on the proximal, side of the lesion. Compensation is brought about by transferring backward to another heart chamber the increased pressure. Compensation is brought about in the stenoses by increased contractile tension, and in the insufficiencies by increased systolic output. As a corollary, to compensate an obstruction hypertrophy is required, but to compensate an insufficiency, both hypertrophy and dilatation must exist" (Moritz).[1] As the result of mitral insufficiency, pressure in the aorta falls, in the pulmonary veins and in the arteries it rises, wherefore the amount of blood in the greater circulation diminishes; in the lesser, increases. The systolic output of the left ventricle increases, that of the right decreases. Distinct dilatation of the right ventricle is not the result of pure mitral insufficiency. Mitral insufficiency leads to dilatation and hypertrophy of the left ventricle. With increase of left ventricular systolic output, the aortic pressure may return to normal and the pulmonic pressure diminish to normal; true compensation is, therefore, possible. In mitral stenosis the work of the left ventricle decreases.

[1] Moritz: Deut. Arch. f. klin. Med., 1899, lxvi, p. 349.

FIG. 25.—MITRAL INSUFFICIENCY.

Showing very extensive tissue destruction. The chordæ tendineæ at the central part of the valvular margin have been destroyed by ulceration, leaving only short shriveled stumps. A few verrucose vegetations are seen. The ventricular wall is much thickened. (Specimen from the Pennsylvania Hospital.)

When mitral insufficiency is *experimentally produced*—by cutting the leaflets or chordæ tendineæ by means of a knife-hook introduced through the left auricular appendage—arterial pressure falls in proportion to the severity of the lesion. *Pressure in the pulmonary artery* is not much altered; it falls somewhat, with extreme insufficiency, and with slight lesions rises somewhat. The systemic venous pressure too shows but little change. The most striking alterations occur in the left auricle, in which pressure rises, distention becomes marked, and the pulsation not only violent, but systolic in time. The latter occurs because the auricle now forms practically a continuous chamber with the ventricle, and the powerful contraction of the latter far over-shadows the feeble pulsation of the former. Mitral insufficiency brings about hypertrophy and later dilatation of the left auricle. The greater the leakage, the greater the dilatation. When regurgitation is less extreme, there is apt to be more hypertrophy (Gibson).

Hypertrophy of the left ventricle occurs on account of the increased amount of blood which this chamber has to handle in order to keep up anything like a normal circulation. But since this merely means that a certain amount of blood is forced back against the lower auricular pressure, it is more likely that the ventricle actually does less and not more work than normal. When marked hypertrophy is present, in such cases, it is often due to other causes, such as arteriosclerosis, etc. Congestion of the lungs generally occurs sooner or later, and this is followed by a train of changes similar to that described under mitral stenosis. Thrombosis of the cavities is common in the later stages, both as an antemortem and as a postmortem occurrence. Left ventricular dilatation enables the ventricle to receive the increased amount of blood which is furnished first by increased auricular activity, and later by right ventricular hypertrophy.

The cause of the right ventricular hypertrophy has been much discussed. The experiments of MacCallum and McClure have

shown that in so far as blood-pressure changes are an index, the pulmonary capillaries may be regarded as a system of rigid tubes, and inasmuch as the left ventricular contractions are transmitted backward into the pulmonary artery with so little loss of time, the contraction of the left ventricle is manifested in the right ventricle during the systole of the latter. An additional cause for right ventricular hypertrophy lies in the fact that when the left auricle becomes dilated, as it early does, it compresses the upper left pulmonary vein between the auricular appendix and the bronchus; left ventricular enlargement tends to compress the left lower pulmonary vein, while right auricular enlargement encroaches upon the right pulmonary veins. Compression of these veins at once produces congestion in the arterial and venous radicles of the lungs and pleuræ. (See Fig. 45.)

Right-sided cardiac hydrothorax or pulmonary congestion often occurs without evidences of stasis in the greater circulation, and, when present, the hydrothorax is generally confined to, or most marked on, the right side. This right-sided localization, which was formerly attributed to pressure by the dilated auricle upon the vena azygos major, has been shown by Fetterolf and Landis[1] to be the result of right auricular pressure upon the pulmonary veins, into which the vessels of the pleura empty. Pressure on the vena azygos major by the dilated right auricle is anatomically impossible. Marked dilatation of the left coronary sinus has simulated an enormously dilated right auricle, seemingly overlapping the left auricle from behind.[2]

"The greater frequency of hydrothorax on the right side is due to the fact that dilatation of the right auricle is more common and more easy than a similar condition on the left side, and such dilatation is the only factor needed to cause damming back in the right pulmonary veins. On the left side in order to include both upper and lower veins there is needed dilatation of the left auricular appendix and the left ventricle, with possibly a retrodisplacement of the vertical septum" (Fetterolf and Landis).

[1] Fetterolf and Landis: Am. Jour. Med. Sci., Nov., 1909, p. 712.
[2] Rollet: Wien. klin. Woch., 1910, p. 119.

V. DISEASES OF THE TRICUSPID ORIFICE

Pathogenesis.—Valvular disease of the right heart is much less common than of the left. This apparently bears some relation to the much greater work which the left heart has to perform, since during fetal life, when this difference does not exist, the proportionate involvement of the two sides is about equal. Two facts which recent investigations seem to have emphasized are that tricuspid disease, while by no means common, is not so rare as has hitherto been supposed, and that when present it is more frequently the result of acquired disease than of a congenital defect. This statement, of course, refers only to actual organic disease of the valve, and not to simple atonic dilatation of the orifice, which is very common. The functional efficiency of this valve depends very largely upon the tone of the sphincter-like muscular fibers surrounding the orifice. Both Harvey and Hunter realized that the tricuspid valve is a much less perfect valvular mechanism than the mitral. We are not surprised to find, therefore, that tricuspid stenosis is one of the rarest, and tricuspid insufficiency one of the commonest, valvular lesions.

Griffith,[1] in an excellent study of 270 cases of tricuspid disease, in which simple dilatation was excluded, has called attention to the foregoing facts. Among 150 specimens of cardiac disease in the Pathological Museum of Yorkshire College studied by him, there were no less than 26 instances of organic tricuspid disease, all of which were apparently acquired after birth. Fenwick[2] and Herrick[3] have arrived at similar conclusions. The latter among 154 cases of tricuspid stenosis found an antecedent rheumatic history in 57, probable rheumatism in 4, chorea in 2. Among 28 there was no such history, and in the remainder the etiologic factor could not be determined. Combining the statistics of Leudet,[4] Herrick, and Griffiths, there was a history of rheumatic fever or

[1] T. W. Griffith: Edinburgh Med. Jour., 1903, lv, 105.
[2] Fenwick: Transactions Pathological Society of London, 1881.
[3] Herrick: Boston Med. and Surg. Jour., 1897, cxxxvi, 245.
[4] Leudet: Paris Thesis, 1881.

chorea in 34.9 per cent. Pitt's [1] series showed a percentage of 62, due to these causes.

Tricuspid stenosis is nearly always associated with other valvular lesions, especially mitral stenosis, as the collected statistics of Herrick show.

Tricuspid and mitral stenosis..................................	102
Tricuspid stenosis alone......................................	14
Tricuspid and pulmonary......................................	1
Tricuspid, aortic, and pulmonary	2
Tricuspid and aortic	64
Tricuspid and mural..	1
	184

In only 6 of the last-named author's cases was there not also some mitral involvement, and in only 4 cases were all the other valves normal. The Guy's Hospital material collected by Pitt showed only 2 among 87 cases without coincident mitral stenosis. These facts alone point very strongly toward an inflammatory origin, although they have been used in explaining the tricuspid stenosis as the result of back pressure from mitral obstruction. But such a result does not follow mitral insufficiency in which there is also back pressure, and, furthermore, actual endocarditic vegetations are not infrequently found on the tricuspid valve. However, some recent investigations have tended to corroborate the back pressure theory. "In view of the work of Goodhart, Roy and Adami, and Weber and Deguy, it is not unlikely that the overstrain of the right ventricle leads to edema and hemorrhage into the tricuspid valve, and that these processes usher in the fibrosis. In other words, the mitral lesion itself becomes an etiologic factor in the tricuspid lesion, and the pathologic process completed in the mitral is now transferred one step back in the circulation and repeats itself in the tricuspid" (Hirschfelder).

TRICUSPID OBSTRUCTION

Occurrence.—At the Philadelphia General Hospital among 8,640 autopsies there were 162 cases of chronic tricuspid endocarditis. There were 58 instances of marked incompetence, 8 cases of stenosis, 4 cases of marked calcification, and 1 case of supernumerary leaflets. Tricuspid obstruction is much commoner in women than in men (133 to 38) and between the second and third decades (Herrick).

Occasionally tricuspid obstruction has a congenital origin. Some cases show a nodular condition of the valves near their margins. In the fetus the blood-vessels extend nearer to the free

[1] Pitt: Allbutt's System of Medicine, vol. i.

margins than in the adult (Darier), and as they retract small areas may remain, which may cause hematomas. Rarely obstruction may be caused by tumors or ball thrombi (Gairdner).

Morbid Anatomy.—From what has just been said it will be evident that the condition of the heart will vary according to the time at which death occurred. During the first stage there will be a hypertrophic enlargement of the auricular wall and of the superior vena cava. During the second stage the caval orifice is found greatly enlarged, so that the auricle and the veins form a continuous sac. Thus, in one case a thrombus was found which extended from the auricle directly backward into the cervical vessels. The auricular myocardium in such cases undergoes atrophy and may become almost a mere fibrous sac formed by the endocardium and epicardium. Pericarditis, sometimes acute, but more frequently the chronic adhesive variety, has been found

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Fig. 26.—Acute and Chronic Endocarditis, Mitral Stenosis.

A. L., white, laborer, aged forty-two years. (Philadelphia Hospital, vol. xviii, p. 210. Physician: Dr. S. S. Cohen. Pathologist: Dr. Funke.)

Clinical Notes: Was admitted complaining of cough, anasarca, and dyspnea. The latter had existed for two years.

Physical Examination: Heart: The apex-beat extends from the fifth to the eighth interspaces in the anterior axillary line. There is no thrill. The dullness extends from the mid-sternal to the anterior axillary lines. A presystolic murmur is heard near the apex when the heart beats strongly. The first sound is loud and booming, and followed by a soft systolic murmur which is transmitted to the axilla, at which point it is loudest. The aortic second sound is feeble, the pulmonic second accentuated, and the heart action tumultuous. A systolic murmur is also heard at the aortic and at the tricuspid area.

The patient improved under treatment until he was able to leave his bed for half an hour. On the second day of his so doing he suddenly fell to the floor, greatly cyanosed, and *died* almost at once.

Pathologic Diagnosis: *Acute and chronic endocarditis, mitral stenosis, pulmonary infarction (anemic), renal congestion.*

Heart: Weighs 500 gm. The right side is dilated, its muscle thin, bright red in color, and its endocardium opaque. The foramen ovale is obliquely patulous. The tricuspid orifice admits three fingers with ease. The right ventricular wall measures 0.5 cm.; it is quite firm, and traversed by yellowish lines which commence in the subpericardial fat. The papillary muscles are firm, and bright red in color. *One of the mitral leaflets contains two fenestrations along its line of contact.* The pulmonary leaflets are normal. The left auricle is distended, thin, pale, and its endocardium opaque. *The mitral orifice barely admits one finger. The left ventricle is large and contains several post-mortem clots, and measures 2.5 cm. at its thickest point,* its muscle being firm and pale. *The mitral leaflets are thickened, shortened, and adherent, especially at the inner angle.* On the posterior surface are numerous small, pendulous, pinkish vegetations, about 4 mm. in length, which are adherent to the leaflets. *The aortic leaflets are slightly thickened,* especially at their bases.

Fig. 26.

with somewhat astonishing frequency. In so far as the valves are concerned the structural changes which have been noted are practically those which are met with in other varieties of endocarditis—vegetations, sclerosis, changes in the chordæ tendineæ, papillary muscles, etc. (See Figs. 23, 24, 28.) In two instances pedunculated tumors have been reported. Perhaps the most frequent finding has been a fusion of the valvular curtains, producing a funnel-shaped stenosis. The degree of the latter, of course, varies with the case. In the older writings several references are made to the case of General Wipple, reported by Corvisart, in which the valves were so extensively calcified that only a small slit-like opening remained.

Recent vegetations, even when of considerable size, are more apt to produce an insufficiency than a stenosis. Such high degrees of contraction as are met with in mitral disease are very rarely found, and nearly always the aperture will admit two fingers. The crescentic slit so common in mitral stenosis is rarely found on the right side of the heart, whereas calcification seems to be much more common (Crawford).[1]

Inasmuch as the *congenital variety* of tricuspid stenosis is, so far as we can judge, generally the result of a fetal endocarditis, it is not surprising that the pathologic appearance presents no especial features distinguishing it from the post-natal form. It may, however, be due to true malformation and be associated with other anomalies, such as a persistent ductus arteriosus, imperforate ventricular septum, patulous foramen ovale, etc.

Before closing this section, attention should be called to the fact that, owing to the almost constant association of tricuspid and mitral stenosis, it is often very difficult to determine how much or how little effect the latter has had in bringing about the secondary changes in the heart.

(Figs. 15, 20b, 23, and 24 were from cases of combined lesions; in the first, at least, there was a definite history of rheumatic fever

[1] R. Crawford: Practitioner, 1907, lxxviii, 191.
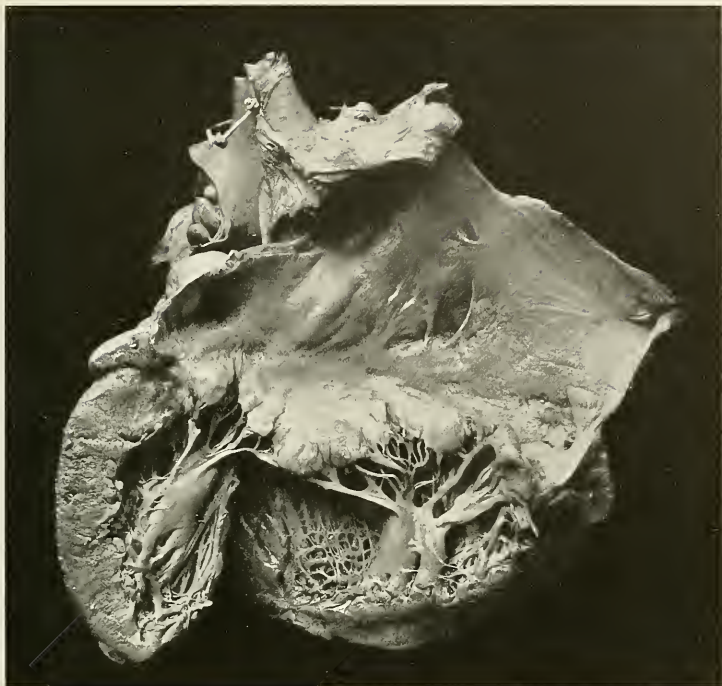
FIG. 27.—CHRONIC MITRAL ENDOCARDITIS.

Female, white, aged forty-three years. (Pennsylvania Hospital. Autopsy No. 309. Pathologist: Dr. Longcope.)

CLINICAL NOTES: Past history negative. For the last six weeks has had abdominal swelling, post-prandial discomfort, slight loss of weight, and some edema of the feet.

A systolic murmur is heard at the aortic area which is transmitted down the sternum. There is also a systolic thrill. Ascites is present. Paracentesis abdominalis was twice performed. *Death* occurred gradually, with the symptoms of peritonitis.

PATHOLOGIC DIAGNOSIS: Carcinomatosis of the peritoneum, etc. *Chronic mitral endocarditis.* Fatty degeneration of the heart, etc.

PERICARDIUM: Contains 100 c.c. of clear fluid. It shows no abnormalities.

HEART: Is not increased in size; it weighs 240 gm., and contains fluid blood and a few postmortem clots. The epicardium contains much fat; it is smooth and glistening and its vessels are not especially prominent. The heart muscle is of a pale yellowish-brown color, and shows yellowish flecking beneath the endocardium of the left ventricle, which is 12 to 15 mm. in thickness. Tricuspid and pulmonary valves are normal. *The mitral valve is thickened along its free edges, the leaflets are slightly retracted, and the chordæ tendineæ are distinctly shortened.* The aortic valves are thickened, not retracted; the corpora Arantii are knobbed. The aorta shows moderate sclerosis, in irregular plaques, and one or more calcified plates. The coronary arteries are patent and smooth. The auricular appendages are free from thrombi.

four years before death.) The diagnosis is, therefore, obviously often overshadowed by the associated mitral lesion. In the few cases of isolated tricuspid stenosis which have been reported, the diagnosis of mitral stenosis was generally made, although there have been several cases in which the condition has been correctly recognized intra vitam, beginning with Gairdner's case in 1862.[1]

Pathologic Physiology.—In case of obstruction of the tricuspid orifice the right ventricle is filled more slowly than normal, and the right auricle hypertrophies. When the stenosis increases or the nutrient blood-supply fails to meet the unusual demands, dilatation follows. Clinically this is well illustrated in the character of the venous pulse. During the first stage the auricular (presystolic) wave is large and well marked; during the second stage, when the auricle becomes overdistended and paralyzed, the veins remain permanently full and cease to pulsate. At first the venous regurgitation into the cavæ is prevented by a hypertrophy of the tenia terminalis and the other fibers which tend to close the caval orifice of the auricle during its systole. Later, stasis and congestion of the portal system, etc., follows. (See Fig. 46.)

TRICUSPID INSUFFICIENCY

Pathologic Anatomy.—The leaflets are generally elongated and thinned, while the free margins are thickened and (contrary to mitral insufficiency) everted. The thickened portion may be soft or indurated, and not rarely on its auricular surface shows localized loss of tissue, resembling ulceration. (This occurred in 17 of Sierro's[2] 38 cases.) These changes occur oftenest on the free margin of the middle leaflet, with the anterior leaflet next in frequency. The chordæ tendineæ are often attenuated and elongated, and the tip of the papillary muscle not infrequently is indurated. The tricuspid opening is enlarged. There is also

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[1] Gairdner: Clinical Medicine, 1862, p. 602.

[2] Sierro: Contribution a l'étude des ulcer. chron. de la valvule tricuspide, Thèse de Geneve, 1886.

Fig. 28.—Acute and Chronic Endocarditis of the Aortic, Mitral, and Tricuspid Valves.

The upper portion of the auricles has been cut away. The three valvular orifices thus exposed show induration and contraction of their component tissues. The mitral valve in addition shows a large dark mass of vegetations of recent origin which almost completely occlude its orifice. The endocardium and myocardium of both auricles are thickened. (Photograph by Dr. Alfred R. Allen.)

a diffuse thickening of the endocardium of the right auricle. The right auricular appendix is dilated and the fossa ovalis depressed. In cases in which the foramen ovale is patent, the surrounding endocardium is additionally thickened. The auricular muscle is at times hypertrophied, again seemingly attenuated (Zahn).

Pathologic Physiology.—Stadler [1] has produced tricuspid insufficiency *experimentally* in rabbits. The animals lived several weeks (nine to one hundred and seventy-six days), and developed ascites, edema, and hepatic enlargement. The hearts were examined by Müller's method and showed distinct hypertrophy of the right auricle and ventricle, but in some marked cases atrophy of the left ventricle occurred, due apparently to the smaller amount of blood handled. In the less severe lesions this did not occur, from which it appears that even tricuspid insufficiency may be compensated by increased vascular tone and hypertrophy of the right auricle, which not only contracts more forcibly but aspirates blood from the veins more powerfully.

Both the heart and the venæ cavæ play an important rôle in maintaining compensation in tricuspid insufficiency. By virtue of the increased venous pressure the right ventricle may be said to contract against a wall of blood which helps to prevent regurgitation. Again, this increased venous pressure causes a rapid filling of the chamber during diastole.

Franke has called especial attention to the rôle of the liver. Inasmuch as all cases of tricuspid insufficiency are not accompanied by ascites, and since neither suction of the right heart nor elasticity of the venæ cavæ are sufficient to explain its non-occurrence, we must assume that the liver plays an important rôle. During systole venous blood is actually forced out of the hepatic cells into the portal system, by the higher pressure which exists in the arterial system. [2]   (See Fig. 46.)

Of course, this really means that the left ventricle is doing

[1] Deut. Arch. f. klin. Med., lxxxiii, 1 and 2.
[2] Franke: Wien. klin. Woch., 1906, No. 31.

the work of keeping up excess pressure in tricuspid insufficiency, just as the right ventricle does in mitral insufficiency.[1] When large quantities of blood are penned up in the veins however, the left ventricle has less to handle and may decrease in size.[2]

In children the tendency to tricuspid insufficiency is minimized by the more horizontal position of the heart. Gravity has thus little effect. The negative pressure created by ventricular diastole, plus the auricular systole, are the chief factors in filling the ventricle (Fetterolf and Gittings).

Relative tricuspid insufficiency is a common lesion. Structurally this valve is inferior to the mitral, and with dilatation of the right heart incompetency is readily induced. This is due not only to relaxation of the tricuspid sphincter, but more especially to the fact that in dilated hearts the origins of the chordæ tendineæ and the papillary muscles are too far from the center of the ventricular cavity to permit perfect valvular closure.[3] Tricuspid insufficiency may occur during parturition, and in various forms of prolonged and arduous labor which necessitate great muscular and intrathoracic straining.

Clinical Considerations.—Gibson has stated that tricuspid insufficiency, far from being a rare lesion, is the commonest of all valvular insufficiencies. This is probably correct if we include the functional regurgitation which occurs after the manner of a safety-valve under great muscular strain, and under other conditions of increased right ventricular pressure. The sweeping statement of Romberg, that "isolated tricuspid insufficiency has not yet been described," evidently does not refer to the relative insufficiency above referred to. The safety-valve effect alluded to, which was first emphasized by T. W. King, of "moderator band fame," although it had been described by earlier writers, is by no means universally accepted as a fact.

[1] Calvert: Arch. Int. Med., April, 1908.
[2] Stadler: Arch. f. klin. Med., 1905, lxxxiii, Heft 1 und 2.
[3] Krehl: Arch. f. Anat. u. Physiol., 1889, p. 289.

VI. DISEASES OF THE PULMONARY ORIFICE

"STRUCTURALLY the pulmonary valve and its surroundings differ from those of the aortic valve in their more delicate texture, and in the fact that in the adult the segments do not, as a rule, show the medial thickening about the corpora Arantii. The wall of the pulmonary artery is thinner than that of the aorta and has not the same tendency to preserve its ring structure in the absence of an internal pressure. The conus arteriosus which leads into the pulmonary artery is more thin-walled than the corresponding part of the left ventricle, and under increased internal pressure is probably capable of considerable dilatation. The structures in relation to the pulmonary valve are obviously directed as a whole to withstanding much less pressure than the corresponding parts of the aorta, and this is borne out by what is known regarding the relative pressures in the two sides of the heart."[1] Among 4,547 autopsies and 238 cases of valvular disease Willigk found 9 cases of pulmonary endocarditis.

PULMONARY OBSTRUCTION

Pathogenesis.— Obstruction of the pulmonary orifice is one of the most rarely acquired, and the commonest of congenital, valvular lesions of the heart. It may be produced by infectious diseases, yet often no such history is obtainable. Some of the cases have been due to sclerotic or gummatous syphilitic lesions. Again, pulmonary stenosis may result from pressure from an aortic aneurism or tumor. Some cases have been ascribed to a fetal endocarditis; against this hypothesis is the fact that the inflammatory condition should remain so localized. In one case reported by Dittrich the etiologic factor appeared to be the kick of a horse on the precordium.[2] From both an anatomic and an

[1] Osler and Gibson: Osler's "Modern Medicine," vol. iv, p. 251.
[2] Dittrich: Vierteljahrsch. f. prakt. Heilkunde, 1849, p. 157.

etiologic standpoint obstruction of the pulmonary orifices is divided into two classes: (*a*) *stenosis* the result of acquired pathologic alterations; (*b*) *atresia*, the result of congenital malformation. Narrowing may occur either at the orifice proper, in the first part of the artery, or in the conus arteriosus. Not infrequently insufficiency of the valve also exists.

Morbid Anatomy.—In the majority of cases pulmonary stenosis is due to an abnormality or hypoplasia of some part of the pulmonary tract, such as the conus, in which the leaflets themselves may or may not be involved. "In these cases a defect of the interventricular septum is usually associated and a deviation to the right of the aorta, so that this arises from both ventricles above the defect. Such forms, which seem to suggest a developmental origin, make up the great majority of cases of pulmonary stenosis, and the combination of these three conditions, pulmonary stenosis, defect of the septum at the base, and *rechtslage* of the aorta, is probably the commonest of all cardiac anomalies" (Abbott). Some cases result from induration, thickening, fusion, or calcification of the valve leaflets without other structural defects, and are manifestly the result of an inflammatory process. According to Keith, the conus of the right ventricle is involved in 90 per cent. of the cases. In most of the cases the right auricle and ventricle are hypertrophied and dilated. With increasing stasis tricuspid insufficiency is often superadded.

Pulmonary stenosis seems distinctly to predispose to tuberculous disease of the lungs. Among 449 cases of the former there were 160 of the latter.[1]

Pathologic Physiology.—"In congenital cases the effect on the heart depends largely on the state of cardiac development at which the pulmonary narrowing is produced. If it appears before the end of the third month, the interventricular septum does not close; if after this date, the foramen ovale and ductus arteriosus may remain patent. The condition of the right ven-

[1] G. W. Norris: "Tuberculosis and Heart Disease," Am. Jour. Med. Sci., Oct., 1904.

tricle varies with the degree of occlusion of the pulmonic orifice. If the opening is completely blocked, the ventricle may remain small and undeveloped, but with less degrees of narrowing the chamber is commonly greatly hypertrophied" (Colbeck).

PULMONARY INSUFFICIENCY

Pulmonary insufficiency is a rare lesion. Only one case was found among 8,640 autopsies at the Philadelphia Hospital, and 24,000 medical cases admitted to the Johns Hopkins Hospital revealed only 3 cases.

Pathogenesis.—Pulmonary insufficiency may result from infective endocarditis, or from the long-continued pulmonary hypertension which occurs in mitral disease, emphysema, and other forms of chronic lung disease. Pitt has called attention to its relative frequency as a result of gonorrheal endocarditis. It occurs in both sexes, is a disease of early life, and is usually associated with obstruction. Sometimes pulmonary sclerosis may be simply a part of a general systemic process. Pulmonary incompetence may result from congenital malformation, although as a rule such abnormalities, which are relatively frequent and generally consist either of an increase or a diminution of the number of leaflets, are unproductive of leakage. Among the Philadelphia Hospital autopsies (8,640) there were 5 cases of supernumerary leaflets, other anomalies 4, fenestration 17. (See Fig. 81.) At times pulmonary incompetence results from aneurism or rupture of a valve.

From a study of 172 reported cases of sclerosis of the pulmonary artery Posselt found the following conditions associated: mitral stenosis, 47; myocarditis, 25; arteriosclerosis, 21; polyarthritis, 20; aneurism of the pulmonary artery, 18; other cardiac lesions, 17; patulous ductus Botalli, 15; adhesive pericarditis, 15; syphilis, 12; emphysema, 12, etc.[1]

It is probable that a relative insufficiency due to dilatation also occurs when pressure in the pulmonary circuit is much increased. Gibson has shown that in a normal human heart post

[1] Lubarsch and Ostertag's Ergebnisse d. allg. Path., 1909, i, 444.

mortem the pulmonary valve begins to leak when pressure is raised to from 16 to 26 c.c. of mercury.

Pathologic Anatomy.—Well-marked changes in the endocardium of the right heart in cases of pulmonary insufficiency are not often found. The pathologic alterations which are frequently encountered in the left heart when the valves are incompetent are generally absent or but slightly marked. The pulmonary leaflets are less thickened and atrophy or sclerosis of the endocardium is less markedly evident. There is, however, generally a dilatation of the right ventricle and of the conus arteriosus.[1]

An unusual case of pulmonary endocarditis causing perforation of the ventricular septum followed by embolic gangrene of the nose and ears, and multiple infarcts in the kidneys, has been reported by Fisher and Longcope.[2] Reitmann[3] has reported symptomless pea-sized hyalo-fibromas in the nodules of Arantius of the anterior pulmonary leaflet in a patient of seventy-four years.

Isolated atheroma and dilatation of the pulmonary artery has been generally regarded as of considerable variety. Romberg's case has been extensively quoted in the literature, and a few other cases are on record. L. Rogers has recently reported 10 cases, and states that the condition is not infrequent in Bengal, where his material was collected.

Marked hypertrophy of the right ventricle was observed, the patients dying with symptoms of right heart failure, and frequently showing hydropericardium, resulting from dilatation of the coronary veins. The valve leaflets nearly always escaped. Contrary to other forms of arteriosclerosis, it occurred most frequently in women. The explanation seems to lie in the fact that these cases are syphilitic in origin. Disease of the pulmonary artery has also been attributed to the artificial plethora of prolonged and excessive beer-drinking.[4] While doubtless most cases of sclerosis of the pulmonary artery are secondary to such cardiac lesions as lead to tricuspid insufficiency, yet some cases have been reported in which the pulmonary sclerosis seemed to be the primary lesion.[5] The most important factors are mechanical—increased or variable blood-pressure, in which intoxication and infection perhaps also play a rôle.[6]

[1] Zahn: Verhandl. d. Kongr. f. inn. Med., 1905, p. 359.
[2] Fisher and Longcope: Proc. Path. Soc. Phila., 1903, p. 98.
[3] Reitmann: Zeit. f. Heilk., xxvi, Abth. f. path. Anat., Heft. I.
[4] Kitamura: Zeit. f. klin. Med., lxv, Heft. I and II.
[5] Sanders: Arch. Internal Medicine, April, 1909.
[6] Laubry and Parvu: Tribune Med., 1909, p. 485.

VII. ACUTE PERICARDITIS

Occurrence.—Pericarditis may occur in any form of general infection. Brooks and Lippincott[1] found that 46 out of 67 cases were due to general bacterial infections. Some of these diseases, such as rheumatic fever and pneumonia, however, are much more prone than others to be thus complicated. It is apparently more common in children than in adults, especially in the rheumatic fever of the second decade, and, as might be expected, in chorea (19 out of 73 autopsies—Osler). Andrew among 1,474 cases of heart disease found 25 cases of pericarditis.

Pathologic Anatomy.—The earliest manifestation of pericarditis consists in a *vascular engorgement*, which spreads from the course of the larger vessels as the process advances. Small localized granulomas occur chiefly at the base of the heart. Associated with this vascular injection the normally transparent and glistening membrane becomes cloudy and roughened as the result of fibrous exudation and of tumefaction of the endothelium. If the deposition of fibrin increases, it is formed into ridges by the friction of cardiac contraction, producing a reticulated appearance which has been compared to honeycomb, the rippled sea, the rugæ of the second stomach of the calf (Corvisart), buttered bread, two slices of which have been separated (Laënnec).

Following the inflammatory engorgement there may be more

[1] Brooks and Lippincott: Am. Jour. Med. Sci., Dec., 1909.

FIG. 29.—FIBRINOPURULENT PERICARDITIS.

D. M., male, aged thirty-six years. (Philadelphia Hospital, vol. xvii, p. 141. Physician: Dr. Hawke. Pathologist: Dr. A. J. Smith.)

PATHOLOGIC DIAGNOSIS: Croupous pneumonia of right upper lobe, plastic pleuritis, fibrinopurulent pericarditis, etc.

AUTOPSY NOTES: The pericardium contains 300 c.c. of slightly brownish, thin, turbid fluid. *Both the visceral and parietal layers are covered with a layer of yellowish plastic exudate, with the characteristic villosities and lines.* The heart with its contained blood and with the pericardium weighs 880 gm. Circumference at the base 78 cm. External length of ventricle, 11 cm.
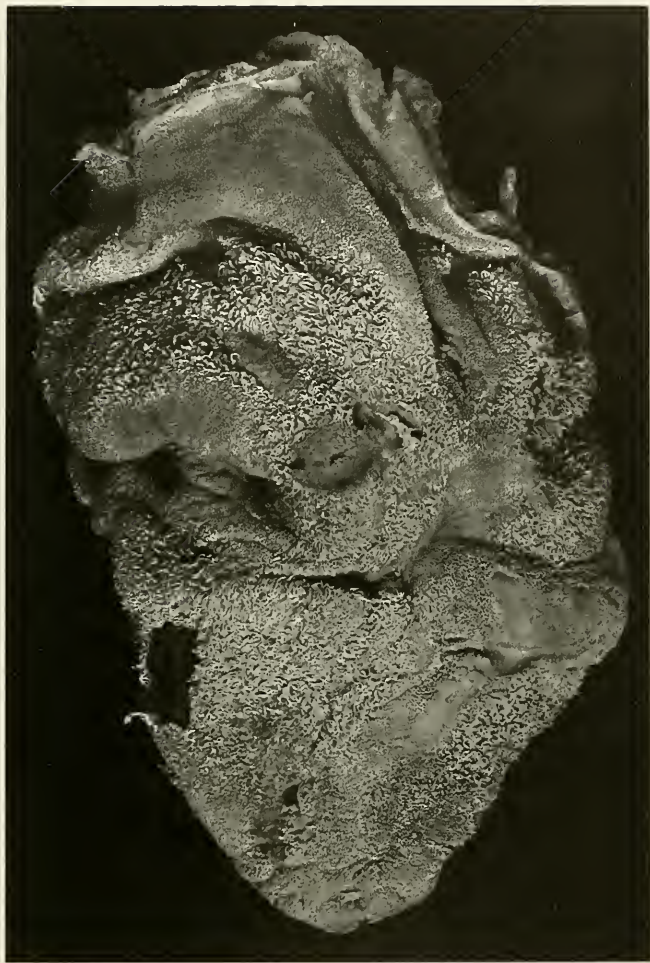
Fig. 29.

or less liquid *exudation,* which may be simply serous or a mixture of serum with fibrin, blood, or pus. In rheumatic fever the exudate is generally serofibrinous. Purulent cases are particularly frequent in childhood, and when the pneumococcus is the offending organism. Blood-stained exudates are met with in tuberculous, cancerous, purpuric, scorbutic cases, and in the terminal stages of Bright's disease. At times considerable blood may be found without evident cause; such cases probably result from microscopic vascular lesions.

A simple serous effusion may be absorbed without permanent damage. If fibrin is present, adhesions are apt to form when the parietal and visceral layers again come in contact. Sometimes such adhesions may be broken up, or, again, permanent synechiæ may remain. The distinction between fibrinous and serofibrinous pericarditis is one of degree only; the essential process is the same. According to Ziegler, vascularization of the exudate from the vessels on the pericardial surface begins by the third or fourth day. Under favorable circumstances more or less complete resorption of even a fibrinous exudate may occur, only a small circumscribed macula or adhesion remaining. As a rule, the visceral layer shows the most marked changes on account of its

FIG. 30.—SUBACUTE FIBRINOUS PERICARDITIS.

J. M., male, aged thirty years. (Pennsylvania Hospital. Autopsy 157. Physician: Dr. Stengel. Pathologist: Dr. Longcope.)

CLINICAL NOTES: Never ill until two months ago, when he developed pain in the left side of the thorax. This eventually proved to be an empyema, which was opened and drained at the hospital (Dr. Spellissy). Heart dullness was increased laterally. The apex-beat was neither palpable nor visible. Death occurred gradually.

PATHOLOGIC DIAGNOSIS: Subacute fibrinous pericarditis. Fibroid tuberculosis; bronchiectasis, etc.

The left lung is densely adherent to the pericardium along its entire length, both lungs being adherent to the parietal pleura, just below the opening of a small sinus which leads from the abscess cavity.

The pericardium is adherent to epicardium, and its sac contains a small amount of purulent fluid. Between the pericardium and epicardium there is a thick fibrinous network of adhesions, giving it a "bread and butter" appearance. The heart muscle is soft and moderately pale. The epicardial fat is abundant, and strands of connective tissue can be seen running into the heart muscle. The left ventricle measures 2 cm. in thickness. The valves are normal; pulmonic orifice 8.5 cm., aortic 8 cm., in circumference.

Fig. 30.

greater vascularity and activity. When pyogenic organisms are present, a great outpouring of leukocytes occurs; the hemorrhagic form is merely the result of the addition of erythrocytes. Trauma may play both a direct and an indirect rôle in the production of pericarditis. Puncture, the injection of turpentine, blows upon the precordium, mediastinal irritation due to prolonged passage of a stomach-tube, may produce pericarditis. The scant blood-supply of the sac doubtless favors infection, and the toxin developed in its neighborhood seems to have a predisposing effect (Charrin). The experimental work of Kuelbs showed that when pericardial lesions resulted from precordial blows, they were generally slight and consisted of small hemorrhages.

The serofibrinous form occurs very frequently in pneumonia, infection seeming to take place through the pleura or mediastinum. The auricles are first and chiefly involved, the visceral layer showing changes later. As the disease advances small inflammatory areas coalesce until the whole heart may be enveloped in a thick, yellowish, fibrinous mold.

The *chemical constituents* of an inflammatory pericardial exudate are practically those of the normal secretion. In some cases, especially the nephritic ones, both alcohol- and water-soluble extractives are somewhat increased (Erben).[1]

A normal pericardium has a capacity of from 180 to 200 c.c. As large an amount as 800 c.c. can be forced into the sac, but anything beyond this is due to stretching—actual enlargement of the membrane (Schaposchikoff and Damsch). The effusion of disease is often much larger than could be forced into a normal pericardium. As was pointed out by Smith and Lusk, this is accounted for by a softening and stretching of the sac which results from the inflammatory processes. The fact that exudates are not absorbed from an inflamed pericardium as they are if drained into a healthy serous cavity, as, for example, the pleura,

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[1] Erben: Klin. u. Chem. Beiträge z. Lehre der exud. Pericarditis, Vienna, 1905.

is perhaps due to pressure of the exudate upon the stomas, and upon the fact that these are plugged with fibrin.[1]

Purulent pericarditis arises if pyogenic organisms are introduced either by way of the blood-stream or the lymphatics, or by direct rupture of an abscess into the sac. Two instances of the latter cases occurred among my 8,640 autopsies. When a serofibrinous exudate undergoes transition into a purulent one, the fibrin becomes more or less liquefied. As a rule, suppurative exudates are smaller than serofibrinous ones. Gas is sometimes found in the sac, produced by the bacillus aërogenes capsulatus. Some years ago James[2] collected 38 cases of pneumopericardium. Twenty-six were fatal. Among those which recovered, 4 were due to stab wounds and 4 to other forms of trauma.

Penetrating wounds generally produce the purulent form of the disease. Rarely such perforation may occur from some object lodged in the esophagus. Flint reported such a case in which the offending object was a set of false teeth. Some very large liquid exudates have from time to time been reported: Sir A. Clark, 4 liters of seropurulent effusion; Osler, 2 to 3 liters; Hirtz, 2,790 c.c.; Thayer, 4,000 c.c.

The *different varieties* of pericarditis have been reported with the following frequency:

	Breitung. (Charité, Berlin.)	Norris. (Philadelphia Hospital.)	Norris. (Pennsylvania Hospital.)
Sero-fibrinous	108	132	44
Purulent	24	23	39
Hemorrhagic	30	18	3
Tuberculous	26 (2 primary?)	22	9
Chronic fibrous	111	304	24
Obliterative	23	16	6
Calcification	2	7	1
Total number of cases	324	529	126

Among 126 cases of pericarditis at the Pennsylvania Hospital

[1] Bergmann (Charité Annalen, 1909, p. 92): A case of large pericardial effusion was tapped so that it emptied itself into the healthy pleura, whence it was rapidly and spontaneously absorbed within three days.

[2] James: American Medicine, July 2, 1904.

cultures were made from the exudate in 54 cases, with the following bacteriologic findings:

Micrococcus lanceolatus	14
Pneumococcus	10
Sterile	10
Unidentified species	6
Streptococcus pyogenes	5
Bacillus coli communis	3
Bacillus lactis aërogenes	2
Bacillus proteus vulgaris	1
Micrococcus zymogenes	1
Mixed infections (included above)	4
Tubercle bacillus	1
Streptococcus mucosus	1
Contaminated cultures	2

The following pathologic conditions were associated with pericarditis: Lobar pneumonia, 43; bronchopneumonia, 9; acute endocarditis, 20; chronic endocarditis, 28; tuberculosis, 18; empyema, 11; mediastinitis, 3; typhoid fever, 4.

Previous disease or trauma may prepare the soil for subsequent pericardial infection. Such infection may occur by way of the blood-stream, the lymphatics, by direct extension, or by perforation.

The parietal layer of the pericardium, according to Bizzozero and Salvioli,[1] contains a single network of lymphatics, which lie deeply embedded in the connective-tissue stroma, and consist of interlacing vessels. Schwartzoff [2] has shown

[1] Bizzozero and Salvioli: Arch. delle Scienze Mediche, vol. ii.

[2] Schwartzoff: Materialen z. Anat. u. Histol. d. Herzens u. s. Huellen, 1874

FIG. 31.—FIBRINOUS PERICARDITIS.

G. B., laborer, negro; aged twenty-six years. (Pennsylvania Hospital, November 16, 1909. No. 2763. Autopsy: 934. Pathologist: Dr. Crispin)

ANATOMIC DIAGNOSIS: Lobar pneumonia of whole right lung. Fibrinous pericarditis with effusion. Fibrinous pleuritis of right side, etc. Cloudy swelling of heart, liver, kidneys, etc.

HEART: Is of usual size, weighs 330 gm. It is covered with a thick, boggy, shaggy, yellow, fibrinous exudate. The pericardial cavity contains 600 c.c. of yellow fluid, turbid with fibrinous shreds and flecks. The right auricle is of normal size, its tips free from thrombi. Tricuspid normal; also the pulmonary. *The anterior leaflet of the mitral valve has quite a thick fibrous edge, but the chordæ are not much thickened or shortened. Papillary muscles are pale and thickened. Ventricular wall 18 to 20 mm. and very cloudy. There are a few yellow plaques on the arterial wall about the aortic valves.*

MICROSCOPIC EXAMINATION: The exudate covering the pericardium contains a moderate number of polynuclear cells. The muscle-cells are much swollen and have a waxy appearance (parenchymatous degeneration).

BACTERIOLOGIC EXAMINATION: From both lungs and from the pericardial exudate small cocci were obtained, occurring in pairs, and Gram-positive.

FIG. 31.

that these vessels drain into the glands which lie in the areolar tissue between the pleura and pericardium. The lymphatics in the visceral layer are much richer and intercommunicate. Nystrom[1] considers the question debatable as to whether the lymphatics of the pericardial cavity communicate with those of the external layer. It would have to be assumed, therefore, that when the pericardium is infected from the bronchial glands the micro-organisms travel in a direction opposite to the lymphatic current, as may occur in carcinoma metastases.

Pathogenesis.—Pericarditis occurs chiefly in infectious diseases—rheumatic fever, pneumococcic, gonococcic, streptococcic septicemias, also in tuberculosis, syphilis, and scarlatina. It occurs as a terminal infection in dyscrasic states, such as chronic nephritis, diabetes, leukemia, etc. More rarely it follows from the direct extension of an empyema, a subdiaphragmatic, mediastinal abscess, or from penetrating wounds or the infiltration of neoplasms. Frequently pericarditis and endocarditis are associated. In rheumatic fever, for instance, this is common. In the suppurative pericarditis of childhood, however, which is nearly always secondary to pulmonary disease, the endocardium generally escapes. Sixty per cent. of the pericarditis of childhood results from empyema, the rest being made up by abscesses, osteomyelitis, pyemia. etc.[2]

At the Philadelphia Hospital among 75 cases of acute aortic endocarditis there were 20 cases of pericarditis; among 75 cases

[1] Nystrom: Arch. f. anat. u. Physiol. Anat., Abth., 1897, p. 361.
[2] Poynton: Heart Disease and Thoracic Aneurism, 1907, p. 168.

FIG. 32.—ADHESIVE PERICARDITIS—COR VILLOSUM.

Wm. M., male, aged fifty-six years. (Philadelphia Hospital, vol. xvii, p. 217. Physician: Dr. Musser. Pathologist: Dr. Coca.)

PATHOLOGIC DIAGNOSIS: Chronic parenchymatous and interstitial nephritis, with renal infarction. *Adhesive pericarditis—cor villosum—acute valvulitis, etc.*

CLINICAL HISTORY: The patient, a moderate consumer of alcohol, was admitted complaining of dyspnea, cough, and asthenia, the first-named having been present for a number of years. Temperature 101°, pulse 80, respiration 30, on admission.

PHYSICAL EXAMINATION: The apex-beat was not palpable. The heart-sounds were almost entirely obscured by râles. The pulse was weak and irregular. The heart-sounds at the base were inaudible and this organ was enlarged to percussion. A sudden convulsion was followed by unconsciousness, ending in death from edema of the lungs. Exploratory puncture of the pericardium had given negative results.
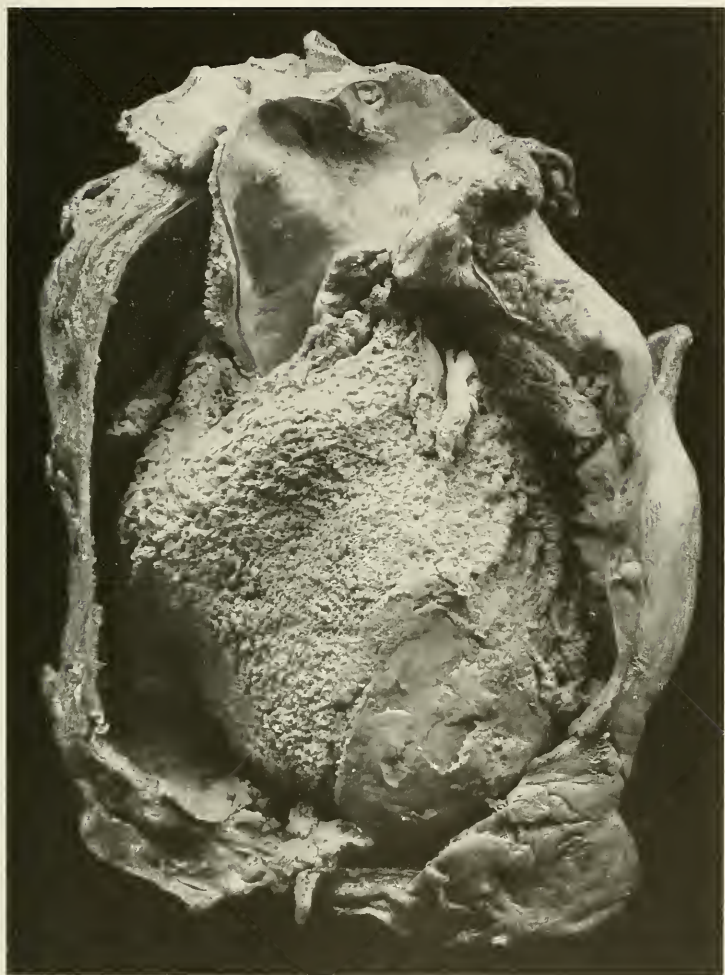
Fig. 32.

of acute mitral endocarditis there were 18 cases of pericarditis; among 10 cases of acute tricuspid endocarditis there were 5 cases of pericarditis.

Among the other lesions found there were fatty infiltration of the pericardium 99, hydropericardium 199, pigmentation 1, maculæ albidæ (exclusive of chronic pericarditis), 84. Brooks and Lippincott found pleural lesions in 136 of 150 cases, acute endocarditis in 10 out of 46, chronic endocarditis in 28 out of 67, acute myocarditis in 2 out of 67.

Hemopericardium results from rupture of a blood-vessel into the sac. Such vessels may be the aorta, the coronary arteries or veins, superficial vessels injured during aspiration, or new vessels formed in the course of inflammatory changes. In the latter case the blood is generally mixed with the exudate. At the Philadelphia Hospital there were 16 cases of hemopericardium in 8,640 autopsies. In cases in which death has resulted from asphyxia, small subpericardial ecchymoses are sometimes found, especially at the base in the neighborhood of the epicardial vessels —"spots of Tardieu." (See Figs. 40 and 41.)

Anthracosis of the pericardium has been reported by Askanazy.[1]

From a clinical standpoint *rheumatic fever* is generally stated to be the most common cause of pericarditis. Among 1,000 cases of this disease at the Bethanien Hospital in Berlin, pericarditis occurred in 100, and endocarditis in 250 of the cases. Well-marked effusion was present in 35 per cent. and slight effusion in 14 per cent. of these; aspiration was necessary in 16 cases.[2]

Rheumatic fever has been credited as the causative factor of pericarditis, as follows: Von Schroetter, 30 per cent.; Harras, 7 per cent.; McCrae, 5.9 per cent.; Williams, 75 per cent.; Leudet, 22 per cent.; Bamberger, 30 per cent.; Bauer, 16 to 20 per cent.; Chambers and Thompson, 20 to 30 per cent.; Phillipps, 4.7 per cent.; Ball and Sibson, 20 per cent.; Wunderlich, 19 per cent.; Duchek, 16 per cent.; Latham, 5 per cent.; Telter, 4.7 per cent.; Eichhorst, 3 per cent.; Taylor, 50 per cent.; Poynton, 75 per cent. (fatal cases); Dunn, 19 per cent.

[1] Askanazy: Zentralb. f. path. Anat., 1906, No. 16, 17.
[2] Zinn: Therap. d. Gegenwart, September, 1909.
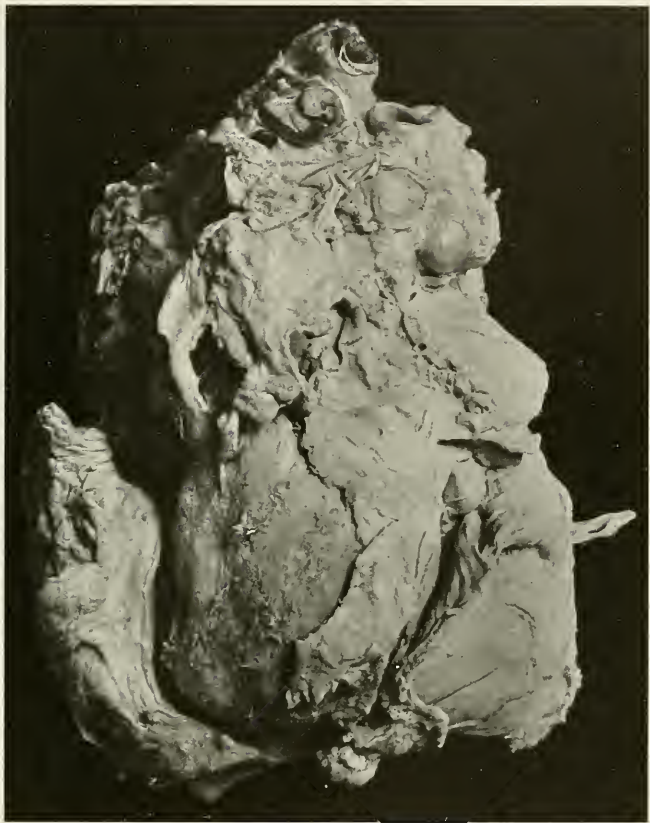
FIG. 33.—CHRONIC ADHESIVE PERICARDITIS.

Showing almost complete obliteration of the sac, with marked thickening and extensive extrapericardial adhesions. (Specimen from the German Hospital.)

(children); Flint, 38 per cent.; Ormerod, 37 per cent. We must bear in mind, however, that "rheumatism" is, and to an even greater extent was, a much abused disease; many different forms of sepsis being included in the term. In Sears' 100 cases of rheumatism, pericarditis occurred in 51 per cent. The frequency of rheumatic infection as an etiologic factor has also been corroborated by the experimental investigations of Wassermann, Poynton and Paine, Cole, Walker and others. Sturges in 100 fatal cases of heart disease, of which 54 were of rheumatic origin, found pericarditis in all but 6. Although there are many exceptions, the pericarditis of rheumatic fever generally occurs relatively early in the attack—within the first two weeks. Chronic valvular lesions with hypertrophy, dilatation, and overaction undoubtedly predispose to it.

As long ago as 1600, Guarinon called attention to the frequency of *pneumonia* as a causative factor of pericarditis; in fact, this infection was blamed for the majority of cases until Bouillaud emphasized the importance of rheumatic fever. *Acute pericarditis*, either serous, plastic, or purulent, occurred 289 times among 2,439 pneumonia autopsies (11.8 per cent.), and 499 times among 40,773 cases of pneumonia (1.2 per cent.) collected by the author. It is by far the commonest cardiac complication, therefore, and stands high up among complications in general. The wide variation in the frequency with which the condition has been reported by different observers shows that, even allowing for errors, the condition is more frequent at certain times.[1] That pericarditis is frequently found unexpectedly at autopsy is well known.

Infection may occur through the blood- or the lymph-streams, but quite often results from direct extension from infected areas of the lungs and pleuræ. In a large proportion of Jürgensen's cases the lingual process of the left upper lobe was diseased. Sears and Larrabee found the right lung diseased in 10 out of 18 cases. Chatard noted the right lung in 13, the left in 5, and both lungs in 13. Kerr found the left lower lobe involved in 12, the right lower in 9, the right middle in 2, and both lower in 3 cases. J. A. Scott, in 76 autopsies on lobar pneumonia at the Pennsylvania Hospital, Philadelphia, found pericarditis in 38 (50 per cent.). In 20 (52.56 per cent.) the exudate was serofibrinous, in 17 (44.7 per cent.) purulent, and in one case the pericardium was obliterated by chronic inflammation. Among 40 cases of pericarditis 22 occurred in pneumonia; in all of these pleuritis coexisted, and in 6 cases both the pericarditis and the pleuritis were fibrinopurulent. In 170 autopsies in pneumonia, Lance and Kanthack found pericarditis

[1] Netter found pericarditis in pneumonia during the years 1837, 1876, 1882, 1886, and 1890 much more frequently than in the intermediate years.

37 times. It was associated with the following conditions: acute endocarditis, 4; pleuritis or empyema, 8; peritonitis, 1; meningitis, 1; synovitis, 1; pleuritis and peritonitis, 2; meningitis and peritonitis, 1; pleuritis and endocarditis, 1. Chatard found the pneumococcus in the pericardium in 19 out of 29 cases, no other important organisms being cultivated.

Some years ago the writer collected from various hospitals in Philadelphia accurate data regarding 1,780 autopsies performed on the subjects of tuberculous disease, and found 82 cases of *tuberculous pericarditis*.[1] Among these statistics cases of simple maculæ albidæ were omitted, as were also all cases in which there was a reasonable possibility that the pericarditis may have been due to other causes than tuberculosis.

Actual tubercles were found in 32, and of the remaining 49, a careful study of the records failed to disclose the evidence of an etiology other than tuberculosis. While there were in the majority of instances no data as to the microscopic appearance of the tissues, it seems reasonable to credit the existence of these lesions to a tuberculous process; for it is well known that the majority of pleural scars and adhesions, so frequently found at autopsies, arise in this manner, although even the microscope fails to reveal either the tubercle bacillus or its characteristic changes. Jaccoud,[2] in 1893, reported a case of complete pericardial symphysis in which all other causes could be positively excluded, and in which tubercle bacilli containing mediastinal glands were the only other pathologic lesions found. In 1885 the same author recorded a case in which the pericardium was macroscopically normal, but in which tubercle bacilli were microscopically demonstrable. In Wells'[3] 24 cases of obliterative pericarditis the bronchial glands were caseous in 10 instances.

In tuberculous pericarditis the heart muscle at times undergoes caseous infiltration and degeneration. This occurred in 5 of my 82 cases; other forms of myocarditis, fatty or fibroid change, are more common. In one of Osler's cases a thin film of auricular appendix alone was found intact; the remainder of the cardiac muscle in that region having undergone caseous necrosis. In the chronic varieties of this disease the heart is frequently enlarged; at first hypertrophied by an effort to overcome the abnormal resistance caused by synechiæ, effusion, or constriction of the large vessels; later, dilated through overwork, malnutrition, and degeneration of its muscle-fibers. The site of the hypertrophy, of course, depends on the location of the increased resistance. The question as to whether hypertrophy will or will not occur depends largely on the

[1] G. W. Norris: Univ. of Pennsylvania Med. Bull., July, 1904.
[2] Jaccoud: Semaine Médicale, vol. xiii, 1893, p. 21.
[3] Wells: Jour. Am. Med. Assoc., May 25, 1901.

8

integrity of the blood-supply and the state of the myocardium at the time when the adhesions form.

Tuberculous pericarditis may occur as miliary tubercles, as large caseous masses, or as simple fibrous thickening, with or without adhesions, in which microscopically no specific tuberculous changes may be demonstrable. With mixed infections any variety of exudate may be formed.

The effusion in tuberculous pericarditis may consist: (1) Of clear serum, its nature being only demonstrable through the presence of pericardial tubercles or tubercle bacilli. (2) Turbid or flocculent fluid is sometimes encountered; usually if fibrin is present, it is adherent to the serous membrane. I found this condition 17 times. (3) Hemorrhagic effusion occurred only 4 times, once coincidently with uremia. Some authors have stated that the aspiration of sanguineous pericardial fluid should lead one to suspect a tuberculous origin, a statement which must be accepted with reservation. (4) Fibrinopurulent exudate was encountered 7 times. In none of these cases was the condition caused by the rupture into the pericardium of a tuberculous lymph-node, as happened in the cases reported by Zenker,[1] Kast,[2] Mickle,[3] Heineman,[4] and Finzi.[5] The amount of effusion in tuberculous pericarditis is sometimes enormous. The largest recorded in my series was Musser's[6] well-known case, in which 1,559 c.c. of hemorrhagic fluid was removed at autopsy.

The varieties of pericarditis as occurring in my series of tuberculous pericarditis may be tabulated as follows:

1. CHRONIC FIBROPLASTIC.

(a) Complete obliterative 24
(b) Partial obliterative 19
(c) Non-obliterative 3

2. ACUTE VARIETIES.

(a) Serofibrinous 12
(b) Fibrinopurulent 7
(c) Fibrinoplastic 3
(d) Hemorrhagic 4
(e) Miliary 10

Tuberculous pericarditis has been found more commonly in men; in the present series it was overwhelmingly so—86 males, 11 females—the sex of 4 having been unrecorded. The ages ranged from seven weeks to seventy-seven years, showing that no age is exempt. The former is, I think, the earliest time of life at which a case has been reported; 22 cases occurred in negroes, being probably about the same proportion to the entire series as the percentage of negroes admitted to the hospitals.

[1] Zenker: Quoted by Osler, Am. Jour. Med. Sci., 1893.
[2] Kast: Virchow's Archiv., Bd. xcvi.
[3] Mickle: Lancet, 1883.
[4] Heineman: Lancet, Dec. 28, 1901.
[5] Finzi: La Riforma médica, Sept. 16, 1903.
[6] Musser: University Medical Magazine, Oct., 1888, p. 32.
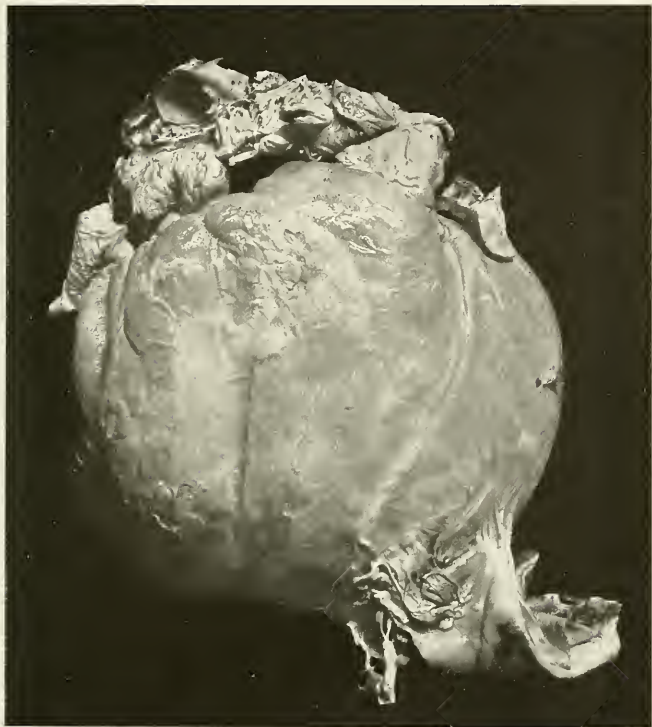
FIG. 34.—CHRONIC ADHESIVE PERICARDITIS.

The visceral layer shows marked thickening and opacities in places. Near the apex there is a large, thick, firm adhesion between the visceral and parietal layers, which presents the evidences of prolonged traction, and doubtless played a considerable part in production of cardiac hypertrophy.

Bamberger was one of the first to point out the frequency of tuberculous pericarditis, he having stated that tuberculosis was second only to rheumatic fever as an etiologic factor, a view which has been reiterated by Osler.

The occurrence of pericarditis in *nephritis* was noted by Bright himself in 8 per cent. of the acute and 6 per cent. of the chronic cases. This was further emphasized by Thomas Taylor, who among 50 autopsies found 5 acute and 7 chronic cases. Sibson among 285 cases of nephritis at St. Mary's Hospital found it in 8.8 per cent., and in 8.17 per cent. of his 1,691 collected cases. Lately it has been found in about 10 per cent. of the cases of interstitial nephritis.

The pericarditis which complicates nephritis is generally a *terminal infection.* Among 255 patients who died from cardiac or renal lesions, Flexner found distinct evidences of terminal infection in 213. The bacteriologic findings in the pericarditis cases were as follows: Micrococcus lanceolatus, 11; streptococcus, 4; staphylococcus aureus, 1; bacillus pyocyaneus, 1; bacillus influenzæ, 1; mixed infections, 2; unidentified species, 1.[1] In 8 of the cases the infection apparently followed pneumonia.

Some observers still believe that purely *toxic cases* may occur.[2] Thus, Chattin found the exudate sterile in 3 out of 4 cases of pericarditis occurring in nephritis: "The existence of aseptic amicrobic pericarditis in certain cases of Bright's disease is well established." Furthermore, pericarditis did not occur in 32 of Flexner's cases of general infection in nephritis, whereas it did occur in 23 in which there was a local infection.[3]

The pericarditis which occurs in nephritis may assume any of the acute or chronic types. A sanguineous exudate seems to be more common than in the rheumatic variety. Both onset

[1] Flexner: Journal Experimental Medicine, 1896, p. 1559.
[2] Banti: Zentralbl. f. path. Anat., 1894, p. 461.
[3] Babcock: Diseases of the Heart and Arterial System, 1903, p. 45.

and course are often insidious, and the termination is usually rapidly fatal.[1]

Gonococcus pericarditis, which is sometimes also associated with endocarditis, generally occurs only in the severe and fatal cases of gonococcus septicemia. In a study of the autopsy records from such cases Tyree found pericardial involvement in 40 per cent.; all forms of exudate were encountered.[2]

Syphilitic disease of the pericardium is probably less rare than has generally been supposed. It is generally a tertiary manifestation which occurs secondarily to myocardial disease, as in the cases reported by Ricord, Mraçek, Herxheimer, and Virchow. Well-marked gummatous lesions have been reported only three times (McPhedran). Often the lesions appear as ordinary fibrous changes. An especial variety has been described by Balzer,[3] consisting of numerous minute aneurismal dilatations of the pericardial vessels, together with thickening or obliteration of the sac. It is not unlikely that future studies based on the finding of the spirocheta pallida will throw much light on the subject. Wacher has recently reported a case occurring as an acute secondary manifestation with recovery under specific treatment.[4]

Laënnec himself excluded "*milk spots*" as not being the results of pericarditis. Recent corroboration of this view is forthcoming as the result of the investigations of Herxheimer,[5] who has described the microscopic appearances as found in a number of specially studied cases. He invariably found the endothelial layer of the pericardium destroyed, and replaced by fibrin, but noted no round-cell infiltration in the underlying or surrounding tissue. He believes, therefore, that milk patches have a *mechanical*

[1] H. B. Allyn: Pennsylvania Medical Journal, 1902, p. 120.

[2] Tyree: International Clinics, Series 18, vol. ii. (A considerable number of cases of gonococcus pericarditis are now on record, reference to which may be found in v. Hoffmann's article, Centralb. f. d. Grenzengeb. der Med. u. Chir., 1903, p. 312.)

[3] Balzer: Archiv. d. Med., 1883, vi, 93.

[4] Wacher: Wien. klin. Woch., 1909, xxii, p. 96.

[5] Herxheimer: Centralblatt f. all. Path. u. path. Anat., 1903, xiv, 737.

origin, being produced by pressure or friction, and not by inflammation.

These conclusions have been corroborated from both an anatomic and an experimental standpoint of Tsunoda,[1] who likens the mechanism of milk spots to the development thickening of the epidermis on the palms and soles as the result of long-continued friction.   He also found that milk spots occurred with increasing frequency as age advanced.

Up to 10 years..	8.5 per cent.
10 to 20 years.	10.0 "
20 to 30 years.	23.0 "
30 to 40 years.	28.0 "
40 to 50 years.	47.0 "
50 to 60 years.	54.0 "
Beyond 60 years.	65.0 "

Primary endothelial atrophy is followed by proliferation of the subendothelial connective tissue.   Many modern text-books, disregarding these researches, still class milk spots as the result of an antecedent pericarditis.

Calcification of the pericardium sometimes occurs.   There were two such cases at the Philadelphia Hospital.   The condition seems to be most commonly a sequel of a suppurative pericarditis.[2]

Oberndorfer has reported a case of board-like pericardial thickening somewhat in the shape of a horseshoe, measuring 11 x 4 cm., occurring in a woman of seventy years and unassociated with symptoms.

At the Philadelphia Hospital an extreme case of myocardial calcification occurred in a man of sixty-five years, in which the process spread from the anterior flap of the mitral valve, involved the whole auriculo-ventricular orifice, the wall of the left ventricle just beneath the endocardium, and the interventricular septum, the heart weighing 550 gm. (Phila. Hospital Autopsy Records, vol. xi, p. 19).

Actinomycosis may produce plastic or suppurative pericarditis.

[1] Tsunoda: Frankfurter Zeit. f. Path., 1909, iii, 220.
[2] Oberndorfer: Münch. med. Woch., 1906, p. 2081.

Fig. 35.—Chronic Adhesive Pericarditis.

J. T., male. (Pennsylvania Hospital. Specimen 46. Physician: Dr. J. M. DaCosta.)
Clinical Notes: Was admitted unconscious and delirious. A diagnosis of meningitis was made.

The pericardium, which was adherent to both the epicardium and the surrounding structures, has been partially dissected back, and shows very marked thickening, and adhesion.

The heart weighed 1,057 gm.

Primary neoplasms of the pericardium are rare. Disease due to the cysticercus, the echinococcus, and trichina has been reported.

Pathologic Physiology.—"The increase of pressure in the pericardial sac is an obstacle to the inflow of blood into the heart, for normally the inflow of blood into the right auricle is greatly favored by the difference in pressure inside and outside the thorax, or, more strictly speaking, outside the thorax and inside the great veins at their entrance into the heart. Since the right auricle receives less blood than normal, it can pass on less blood to the right ventricle, the right ventricle in its turn ejecting less blood into the pulmonary artery; the pulmonary blood-pressure falls, therefore. For the same reason—i. e., because the pulmonary artery receives less blood than normal—less blood reaches the left auricle, and through it the left ventricle, by way of the pulmonary veins. Since the left ventricle receives less blood, its output into the aorta is diminished, and diminution of output of the left ventricle, unaccompanied as in this case by a corresponding increase in the peripheral resistance, is of necessity associated with fall of the aortic blood-pressure. "The venous blood-pressure, on the other hand, rises . . . . because a new condition has been introduced into the circulation which disturbs the hitherto existing equilibrium between the inflow into and outflow from the heart. It is evident, since the aortic blood-pressure is dependent upon the two factors, (a) output of the heart, and (b) peripheral resistance in the arteries, and since the output of the heart, cæteris paribus, depends entirely upon the inflow into the heart, that, for the maintenance of a constant mean level of aortic blood-pressure, the inflow into the heart and the output must be exactly equal. But the blood which constitutes the 'inflow' is nothing more than that amount of blood which, as the result of hyperdistention, passes from the arteries into the veins during cardiac diastole. In other words, for the maintenance of a constant aortic blood-pressure the amount of blood which passes from arteries to veins during a given cardiac diastole must be
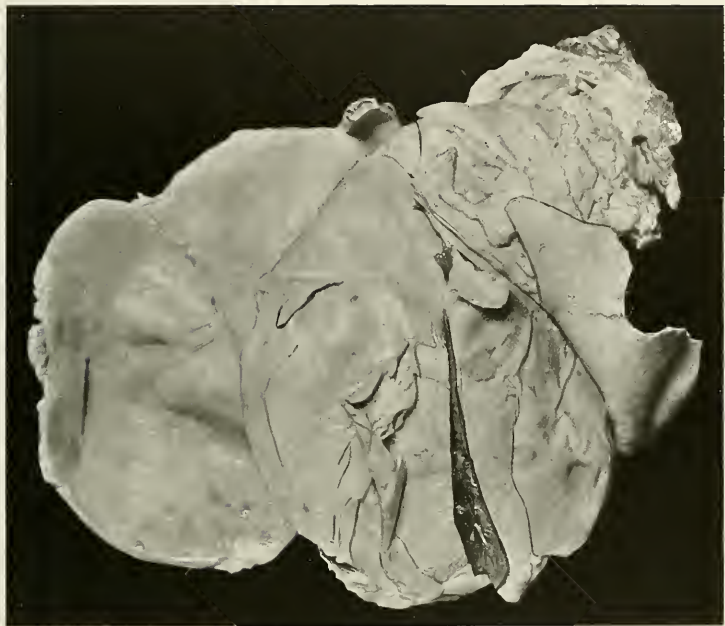
FIG. 36.—CHRONIC ADHESIVE PERICARDITIS.

This specimen illustrates the "Zuckergusshertz," so called owing to the resemblance of the exudate to the sugar icing on a cake. It is generally met with in association with "pericardial pseudocirrhosis of the liver." (Specimen from the German Hospital, Philadelphia.) See page 124.

exactly equal to the amount of blood which has been thrown into the arteries during the previous cardiac systole, and vice versa.

"In the case of a dog into whose pericardial sac oil is injected, the output of the heart is diminished, but since, at the moment before this occurred, the hyperdistention of the arteries corresponded to a greater output, the amount of blood which passed from arteries to veins also corresponded to that greater output. More blood, therefore, leaves the arterial system during any given diastole than enters it during the succeeding systole; an additional amount of blood, therefore, becomes stored up in the veins with each heart's diastole until equilibrium is once more established, gradually leading to the rise in venous pressure which we have noted. . . . . It is this rise of venous pressure which renders maintenance of the circulation possible under the altered conditions, for it is obvious that if the pericardial pressure were raised to, say, 25 mm. of oil, while the pressure in the external jugular and other veins outside the thorax remained at their normal point, no blood would flow into the right auricle at all and the circulation would immediately cease. . . . . As it is, however, the venous pressure rises with the intrapericardial pressure, and always maintains a slight superiority; blood, therefore, flows into the right auricle, and though the pressures in arteries and veins are altered, the circulation goes on. . . . . But the pressure which can be attained in the venous system has a limit which varies with many factors. . . . . So long as the intrapericardial pressure is below (the extreme limit), the circulation continues, however poorly; but once the intrapericardial pressure reaches this point, all possibility of inflow from veins to auricles ceases and circulation comes to a standstill—the whole of the blood of the body collected in the veins. . . . . The heart, however, in experimental cases, for a minute or thereabouts continues to contract, and if, during this time, the intrapericardial pressure be reduced, circulation re-establishes itself." (Lazarus Barlow.[1])

[1] Quoted, McFarland, Textbook of Pathology, 1904, p. 398.

Pericarditis, although a serious condition, is *per se* rarely the direct *cause of death*. Brooks and Lippincott only found 6 such cases among 150. In 86 death was due to septic processes; 17 were terminal infections. In the serofibrinous cases death was due to inflammatory processes outside the pericardium as follows: lobar pneumonia, 30; bronchopneumonia, 4; empyema, 1; acute endocarditis, 9. Not included in the above there were 4 cases of myocarditis and 4 cases of acute tuberculosis. Pericarditis greatly increases danger of endocarditis during both the acute and the chronic stages.

According to Theodore Fisher, pneumococcus and septic pericarditis does not produce cardiac dilatation in the way that the rheumatic variety does, a fact which he explains as due to the deleterious effect of the toxin of the latter disease upon the myocardium.

There is some ground for supposing that under normal conditions the pericardium acts as a support which prevents undue sudden cardiac dilatation, as suggested by Hill and Barnard, and that an inflamed and softened and relaxed sac may be a factor in the production of dilatation.

In chronic pericarditis death is seldom dependent directly upon the pericardial lesion. Of the last-named author's cases, 5 died of cardiac dilatation, 1 of acute endocarditis, 8 of lobar pneumonia, 9 of sepsis, 1 of empyema, 9 of tuberculosis, 6 of alcoholism, 4 of syphilis, 2 of traumatism, 4 of non-specific myocarditis.

Until recently there has been much discussion regarding *the position of the heart in cases of pericardial effusion*. A good deal of light has been thrown upon the problem by Damsch, Schaposchnikoff[1] and Calvert.[2] The position of the heart seems to depend entirely upon its specific gravity; in other words, upon its size and upon the amount of blood it contains, and these factors, in turn, depend upon the amount of intrapericardial pressure and the efficiency of compensation. With advancing severity of the disease the heart contains less blood and the pericardial pressure increases. While the heart is normal in size it remains in a normal position; when it becomes smaller, it is pushed upward and backward, the apex being pushed slightly to the right.

[1] Schaposchnikoff: Revue de Médecine, 1905, p. 789.
[2] Calvert: Bull. Johns Hopkins Hosp., Oct., 1907.

VIII. CHRONIC PERICARDITIS

Pathogenesis.—If the exudate of an acute pericarditis is absorbed slowly, or if it is mainly fibrinous in character, adhesions are apt to form as the result of gradual organization of the exudate. These adhesions may remain as localized circumscribed white areas, or they may, in the form of bands or threads, unite the visceral to the parietal layers, or bind the external surface of the pericardium to the surrounding mediastinal tissues. The most frequent site for such adhesions is on the surface of the right ventricle; next upon the auricles; and lastly, upon the left ventricle.[1] (See Fig. 34.) Mediastinitis may precede or follow pericarditis. In the former case the infection generally spreads from the bronchial or mediastinal lymph-nodes or from the lungs themselves.

Mediastinitis has been divided into three classes: (a) Obliteration of the pericardial cavity with marked increase of mediastinal connective tissue, with or without caseation. (b) Obliteration of the pericardium with extensive adhesions to the surrounding structures, without much increase of mediastinal tissue. (c) Mediastinitis without pericardial involvement.[2]

The most important adhesions are those which occur between the external surface of the sac and the surrounding structures, since it is in these cases that the heart is to the greatest extent hampered and restricted in its action.

When in addition to the pericardium, the mediastinum, pleuræ, liver, and omentum are also involved, we have what has been described as *pericardial pseudo-cirrhosis of the liver* (Pick's disease). Both the heart and the liver are covered with a thick white layer of inflammatory product, so that they have the appearance of being coated with "icing," hence the German name "Zuckerguss Leber

[1] Sicard: New York Med. Jour., 1907, p. 488.
[2] Harris: Medical Chronicle, 1895.

Fig. 37.—Acute Fibrinous Pericarditis.

A specimen from the University of Pennsylvania Museum showing the typical "cor villosum," or "shaggy heart." (The entire heart could not be better reproduced owing to the difficulty of photographing through the convex surface of the hermetically sealed jar in which the specimen was preserved.)

und Herz."[1] This condition is generally a part of an extensive multiple serositis, often tuberculous in origin, and is associated with ascites and signs of portal stasis. Head collected 55 cases of this kind, and added 4. He found that one-third of the cases occurred in persons under twenty years of age. The commonest causal factor was rheumatic fever, although tuberculosis, pneumonia, nephritis, and chorea were also accountable. Pericardial pseudo-cirrhosis has been approximately reproduced experimentally, by the injection of iodin into the pericardium. The inflammatory reaction which followed, by constricting the vena cava, produced congestion and ultimately cirrhosis of the liver.[2] (See Fig. 36.)

Clinically, two varieties of chronic adhesive pericarditis may be distinguished: (a) adhesions followed by marked hypertrophy; (b) complete obliteration without or with only vague symptoms and with few or no adhesions between the pericardium and the

[1] Study of 39 cases, A. O. J. Kelly: Am. Jour. Med. Sci., Jan., 1903.

[2] Hess: "Ueber Stauung u. chron. Entzundung. i. d. Leber u. d. seroesen Hoelen," Marburg, 1902. Fletch and Schlossberger: Zeit. f. klin. Med., 1906, lix, 1.

FIG. 38.—TUBERCULOUS PERICARDITIS.

J. L., male, negro. (Pennsylvania Hospital. Autopsy No. 277. Pathologist: Dr. Longcope.)

CLINICAL NOTES: Patient was admitted to the surgical wards with a history and physical signs of appendicitis. Death occurred from purulent peritonitis.

PATHOLOGIC DIAGNOSIS: Tuberculous pericarditis, etc.

PERICARDIUM: Both layers are firmly adherent, and have to be dissected apart. On separation, they are found to be covered with *small, more or less discrete, opaque, white elevations. Occasionally these coalesce and form a lobulated mass about 1 cm. in diameter, the smaller ones being of a millet-seed size. Both parietal and visceral pericardium are much thickened, the former in many places measuring 5 mm. On section the entire pericardium seems to be composed of nodules, all of which are very firm and never umbilicated. They do not invade the myocardium,* which is firm and dark reddish-brown in color. The tissue between the nodules is dark purplish-red in color and appears to contain hemorrhages. There are no nodules on the external portion of the visceral pericardium. The left ventricle measures 1.5 cm. in thickness. The heart is somewhat enlarged; the cavities are of fair size, and all the valves are thin and delicate.

MICROSCOPIC EXAMINATION: No especial changes are noted in the myocardium. The pericardium is the seat of extensive tuberculosis. Covering the heart muscle there is a thick layer of granular tissue, composed chiefly of epithelioid cells and small round-cells. Everywhere throughout this tissue one sees enormous giant-cells and typical tubercles. In the granulation tissue surrounding the tubercles blood-vessels are fairly numerous. There are no areas of caseation.

(Case reported by the author, Univ. of Pennsylvania Med. Bull., July, 1904.)
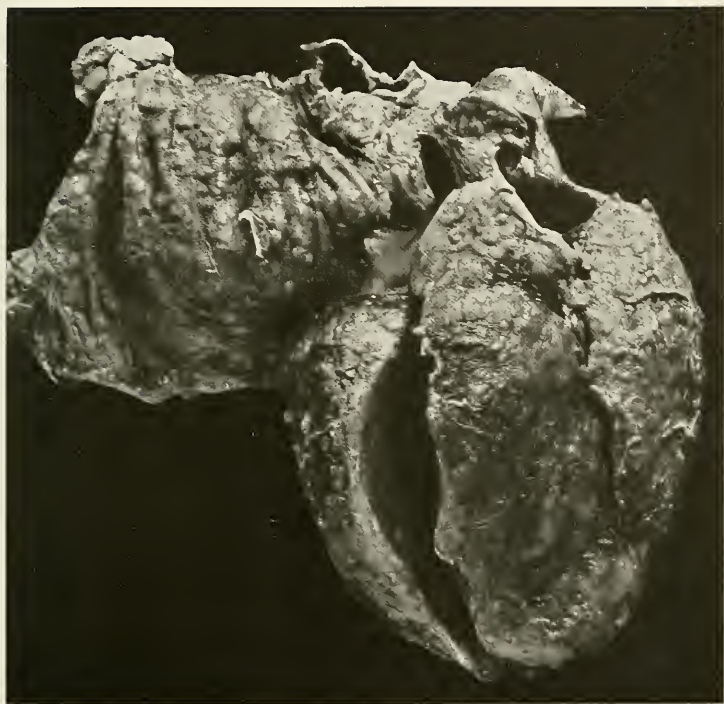
Fig. 38.

surrounding structures. The latter is met with chiefly in males, is independent of valvular lesions, and often occurs in individuals who give no history of antecedent infections. The former variety, which is often seen in valvular disease, is associated with marked hypertrophy and dilatation, and with extensive extrapericardial adhesions. Calcification of the pericardium sometimes follows, and myocardial atrophy resulting from constriction has been described.

Fenton[1] found that "out of 150 cases of adherent pericarditis, in which the cause of death was specifically stated in the postmortem records to have been the direct result of the heart lesions, 65 were found during the first three decades, and 17 during the last four; while where death followed upon causes unconnected with the heart, 13 only were found during the last three decades, and 55 in the last four." He also found a history of rheumatic fever in most of the cases under thirty years, and in relatively few beyond this age; and, further, that the rheumatic cases were generally the serious ones.

Valvular disease was present in 91 cases, absent in 76; total, 167. General adhesions were found in 153 cases, partial adhesions in 17; total, 170.

The extent of the adhesion is certainly no index of the severity of the lesion, but extrapericardial adhesions doubtless play a part in the production of hypertrophy and dilatation, as does also valvular disease when present. Probably the most important etiologic factor in the production of hypertrophy and dilatation is the myocardial damage which so commonly begins just beneath the pericardial lesions, and tends to progress.

"Valvular incompetence will exaggerate the tendency to heart failure by an additional demand upon cardiac reserve; at the same time everything depends on the extent of original damage sustained by the muscle." "Dilatation takes place during the acute and subacute periods of the phase which precedes the chronic adhesion. In a few mild cases it may pass off, but in the great majority it does not, and hypertrophy and external adhesion follow; resulting in a condition of unstable equilibrium in which the constant tendency is to increase dilatation and failure, owing partly to a

[1] Fenton: Practitioner, 1908, lxxxi, 637.

FIG. 39.—TUBERCULOUS PERICARDITIS.

Section of the heart and pericardium from a case of tuberculous pericarditis, showing complete obliteration of the sac, with thickening and caseation. (Photograph by Dr. Alfred R. Allen.)

certain amount of embarrassment to systole caused by external adhesions, but mainly to permanent damage to the heart muscle, in a manner resembling those cases of chronic cardiac failure in more advanced life" (Fenton).

Pathologic Physiology.—"The mechanical effects upon the circulation due to pericardial adhesions may be threefold: (1) The work of the ventricle is increased by the tug upon the adhesions. (2) The filling of the heart may be hindered by strangulation of the vena cava. At each contraction the heart must not only drive out the blood, but must pull on its harness of adhesions. The additional work which it thus has to perform depends both upon the tightness of the adhesions and upon the weight or rigidity of the structures pulled. The latter factor depends upon the position of the adhesions, whether it is the ribs, pleura, mediastinum, or the diaphragm and liver that are tugged upon, being greatest for adhesions to the ribs and diaphragm. (3) The emptying of the heart and the flow through the aorta may, as claimed by Kussmaul, be hindered by the tugging of the adhesions upon the arch of the aorta. This can readily be shown experimentally if such traction be made in a dog whose chest has been opened. The pulse may be made to disappear absolutely in spite of the fact that the heart-rate remains unchanged and the heart dilates from overfilling; enough blood flows in from the venæ cavæ to dilate the heart.

"When this additional work is imposed upon a heart already weak, it may succumb to the strain, and death may occur with all the manifestations of broken compensation. The importance of adherent pericardium in causing death from heart disease is shown by the fact that it was present in almost all the cases of Sturges' series.

"Usually, however, the ventricles gradually recover from the strain and simply undergo a gradual work hypertrophy proportional to the additional strain, and an additional amount of work may be done at each systole sufficient to balance the amount

FIG. 40.—HEMOPERICARDIUM.

The pericardium has been reflected to the left and shows the heart covered with a thick, dark, massive blood-clot which has resulted from the rupture of an aortic aneurism into the pericardium. The aorta is greatly dilated and its endocardium is roughened by extensive calcareous deposits. (Specimen from the Philadelphia Hospital.)

required. During exercise, emotion, disease, or other strains, however, not only the work of the heart in the circulation is increased, but with the increased systolic output and systolic excursion of the walls the tug upon the adhesions is increased enormously, and the heart is thus readily overstrained. The heavy beating of the heart under emotional excitement is especially likely to bring this about.

"Moreover, the process of hypertrophy is not a pure one. With the fibrosis of the pericardial adhesions outward, the process of fibrosis also extends inward into the somewhat injured myocardium, and this process goes on progressively with each moment of overstrain until the myofibrosis cordis is advanced and the heart failure complete.

"The site of the adhesions determines not only the degree but the character of the heart failure. If the densest adhesions are over the left ventricle, the effect is to inhibit the action of the latter alone. Nature performs the experiment of Welch, and gives rise to the clinical picture of broken pulmonary compensation with dyspnea, cardiac asthma, or pulmonary edema.

"If the chief adhesions are over the right ventricle, broken systemic compensation sets in, with venous stasis, tricuspid insufficiency, enlargement of the liver, and collection of fluid at various sites, but particularly in the peritoneal cavity.

"On the other hand, the tugs of the adhesions on auricles and ventricles may act as mechanical extra stimuli and produce an extrasystolic arrhythmia, which in itself hinders the circulation." (Hirschfelder.)

Frequency.—Among 2,000 autopsies at the Presbyterian Hospital in New York, Sicard found 77 cases of fibrous pericarditis ($3\frac{1}{2}$ per cent. of all autopsies). It was extensive in 45, and slight in 32 cases. Mediastinopericarditis occurred only once, endocarditis was associated in 33, severe aortic sclerosis in 4, marked coronary sclerosis in 15, aneurism in 4, chronic nephritis in 33,
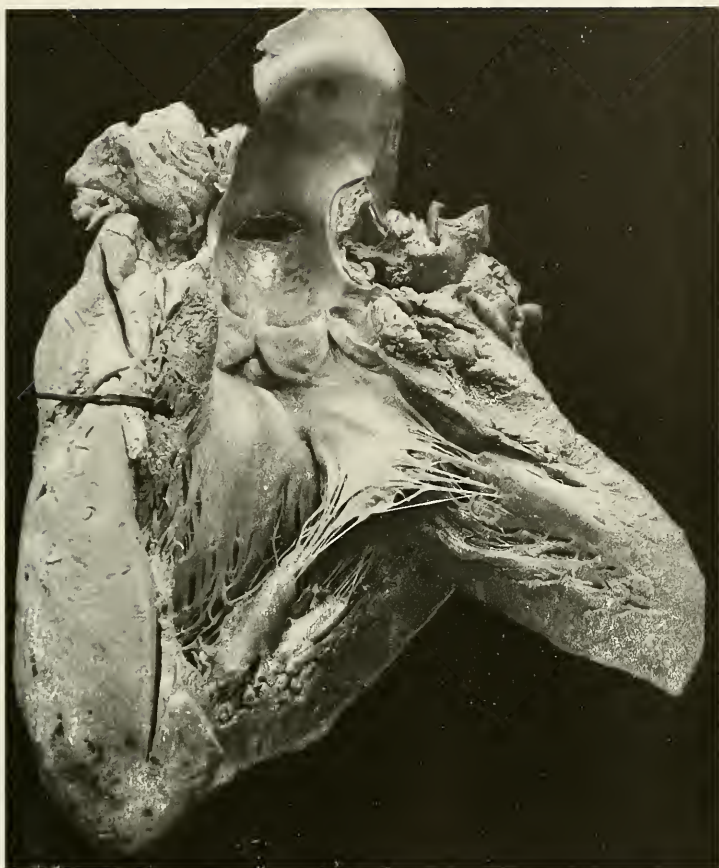
FIG. 41.—RUPTURE OF THE AORTA.

CLINICAL NOTES: Sudden death without premonitory symptoms during convalescence, six days after an operation for hemorrhoids.

PATHOLOGIC NOTES: Two and one-half centimeters above the attachment of the aortic valves there is *a rough, slightly shaggy looking tear running directly across the aorta.* It is 2 cm. in length and leads directly from a small aneurismal pouch into the pericardial cavity. The surface of the aorta along the ascending arch shows small, scattered, yellowish nodules. (Specimen from the Pennsylvania Hospital. Pathologist: Dr. G. C. Robinson.)

tuberculosis in 9. Leudet in 1,002 autopsies found partial adhesion in 5 per cent., total adhesion in 2.5 per cent.

Congenital defects of the pericardium are very rare. The sac may be wanting in acardiac monsters, and sometimes even when the heart is present, or it may only partially cover the heart. Ebstein collected 32 cases of congenital absence, and found that the clinical picture in many respects resembled the "movable heart."[1]

The following pericardial lesions were encountered among 9,940 autopsies:

	Philadelphia Hospital	Pennsylvania Hospital
Carcinoma (metastatic)	3	0
Sarcoma (metastatic)	5	1
Calcification	7	1
Rupture of abscess into	2	0
Gumma	1	0
Rupture of aneurism into		2

Neither the sarcomas nor the carcinomas enumerated in the foregoing statistics were primary. In the case of tumors originating in the heart, pericardial involvement is very rare. Among 61 cases of cardiac neoplasms Schoeppler[2] found the pericardium involved only once.

Clinical Considerations.—The existence of primary pericarditis is no longer admitted. Whenever a true inflammation of this sac occurs, it is due to an antecedent infection of the blood-stream, lymphatics, or contiguous structures. The cases which were at one time believed to have a toxic origin are now known to be infections. "Milk spots" have a mechanical origin which is of a non-inflammatory nature.

No serious cardiac lesion is so frequently overlooked. Cabot[3] found that of 54 cases of acute pericarditis at the Massachusetts General Hospital, 70 per cent. were not recognized ante mortem. Any one who is familiar with autopsy records will realize that a similar state of affairs is the general rule elsewhere,

[1] Ebstein: Münch. med. Woch., March 8, 1910.
[2] Schoeppler: Münch. med. Woch., 1906, liii, No. 45.
[3] Cabot: Jour. Am. Med. Assoc., 1910, p. 1343.

owing to the fact that the onset of a pericarditis is generally insidious, and that such symptoms and physical signs as it does present are usually completely overshadowed by the conditions which it complicates. The obvious lesson to be learned, therefore, is to look actively for signs of pericardial involvement in conditions such as pneumonia, rheumatic fever, nephritis, tuberculosis, empyema, etc., in which it so often occurs.

IX. CARDIAC HYPERTROPHY

DIMENSIONS OF THE NORMAL HEART.—(*Bizot.*)

	Males (Meters)	Females (Meters)
Length of the heart	0.097	0.092
Breadth of the heart	0.107	0.099
Thickness of the heart	0.038	0.031
Length of the left ventricle	0.066	0.072
Breadth of the left ventricle	0.119	0.104
Length of the right ventricle	0.084	0.075
Breadth of the right ventricle	0.188	0.172
Thickness of the Walls of the Left Ventricle:		
At the base	0.010	0.009
At the middle	0.011	0.010
Near the apex	0.008	0.007
Thickness of the Septum Ventriculorum:		
At the middle	0.011	0.009
Thickness of the Walls of the Right Ventricle:		
Base	0.004	0.003
At the middle	0.003	0.002
Near the apex	0.002	0.002
Breadth of the Auriculo-Ventricular Orifices:		
Left ventricle	0.100	0.091
Right ventricle	0.122	0.106
Breadth of the origin of the aorta (above the valves)	0.069	0.063
Breadth of the origin of the pulmonary artery	0.071	0.066

The heart of an adult man averages 300 gm.; of a woman, 250 gm.

The size of the cardiac orifices is given by Perls as follows:

	Under Forty Years.	Between Forty and Fifty Years.	Over Fifty Years.
Aortic orifice, cardiac	70.9 mm.	74.6 mm.	74.3 mm.
Aortic orifice, arterial	63.5 "	72.2 "	80.1 "
Pulmonary orifice, cardiac	81.5 "	84.9 "	85.7 "
Pulmonary orifice, arterial	71.9 "	74.6 "	81.3 "
Mitral orifice, periphery	102.5 "	105.1 "	102.0 "
Tricuspid orifice, periphery	121.0 "	122.0 "	122.8 "

It appears, therefore, that there is a difference not only in the size of the aortic and pulmonary orifices, depending upon whether they are measured at the opening of the heart proper or at the attachment of the semilunar valves, but also that the proportion of these two dimensions to each other is directly reversed before and after forty years of age. "In middle life the unfolded valves take up a greater space than that which they must actually cover, while in old

age they generally take up a smaller space." These facts help to explain the greater frequency of insufficient valves in old age.[1] This increase in the size of the vessels is due to diminished elasticity of arteriosclerotic vascular walls. Arteriosclerotic aortæ are often overlooked because they simply show dilatation, without sclerotic patches.[2]

The size of the heart is proportionate to bodily weight,[3] and to a lesser extent to stature. In adolescents, in corpulent subjects, and in women the size of the heart is relatively smaller than in adult men of the same proportions, especially those with good muscular development. It also increases with age, but enlargement to the left, as shown by percussion or by the orthodiagram, is not solely due to hypertrophy, but also to the fact that in advanced years the organ lies more to the left. The dome of the diaphragm sinks, and with this descent the heart moves downward and to the left.

In early life the upper cardiac border reaches the second, and in adult life the third, costal interspace. The diaphragm being more highly placed in women, the heart is correspondingly higher in position. The lower cardiac border is found in 52 per cent. of male adults at the angle of the costosternal junction, in women in 70 per cent. (Müller, Hirsch, Dietlen).[4] In men the weight of the heart to the whole body is about 1 to 170; in women it is 1 to 183.

Occurrence.—Hypertrophy of the heart consists of an increase in either the number or the size of the muscle-cells, or both. Practically, however, hypertrophy of the heart as generally seen is in part also due to an increased amount of connective tissue, fat, and blood-vessels. It is directly due to an increased demand for work, arising either within or without the heart—valvular lesions,

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[1] Quoted, Rosenstein: Ziemssen's Cyclop. of Med., vi, p. 13.

[2] Scheel: "Study of 500 Autopsies," Norsk Mag. f. Laegevidenskaben, June, 1907.

[3] In animals which have been starved the heart diminishes in proportion to the loss of bodily weight, and regains its original size (as shown by the orthodiagram) when feeding is resumed. This decrease in size seems to be due partly to actual loss of substance, and partly to a decreased volume of blood. One animal in the course of nine days lost 51 per cent. of its total blood. (Schieffer: Deut. Arch. f. klin. Med., 1907, xcii, Dec. 28.)

[4] Müller: Die Massenverhaeltnisse des menschlichen Herzens, Berlin, 1878. Hirsch: Deut. Arch. f. klin. Med., 1899, p. 597. Dietlen: Deut. Arch. f. klin. Med., Oct. 24, 1906.

congenital defects, pericarditis, scoliosis, cardiac thrombosis, aneurisms, neoplasms of the mediastinum, arteriosclerosis, gout, lead-poisoning, etc. Although hypertrophy may affect only one chamber, this is unusual. Hypertrophy has also been ascribed to defective innervation. Although a common cause of hypertrophy is arterial hypertension, yet the continued rapidity of action which occurs over years of time in hypotension may produce a similar result. Thus we see hypertrophy associated with hyperthyroidism.

Systematic writers have been wont to recognize *three types* of cardiac hypertrophy: (1) Simple enlargement, without change in the size of the cavities; (2) concentric enlargement, with dimi-

FIG. 42.—CONCENTRIC CARDIAC HYPERTROPHY.

W. B., negro, laborer, aged forty-five years. (Pennsylvania Hospital. No. 1442 (1908). Physician: Dr. A. Newlin. Pathologist: Dr. Krumbhaar.)

CLINICAL NOTES: Delicate as a child. Healthy at eighteen years. Hard worker. Alcohol and tobacco to excess. Syphilis probably. Six months ago nausea and vomiting, with increasing headaches. Brought to hospital unconscious and soon died.

PATHOLOGIC DIAGNOSIS: Tumor of the pituitary body, etc. *Acute mitral endocarditis. Chronic mitral and aortic endocarditis—concentric cardiac hypertrophy.* Arteriosclerosis of the aorta, etc.

Pericardium contains 10 c.c. of clear fluid; no adhesions.

HEART: *Weighs 530 gm., enlarged and firm.* Normal color. Epicardium grayish, and diffusely thickened. In spots, dense white, opaque areas, which cut with resistance. Epicardial fat increased. Epicardium over right auricle tessellated with slight raised, grayish, pin-point nodules. Right ventricle 6 to 10 mm. Auricular and pulmonary valves normal. *Left heart empty, its musculature enormously increased; measures 18 to 22 mm. Its cavity smaller than would be expected.* Endocardium smooth and glistening, though on the septal wall *some of the vessels seem dilated. Mitral orifice 10.5 cm. and shows, especially on the anterior leaflet, diffuse fibrous plaques. Along the whole line of closure are minute grayish vegetations of pin-point size. Aortic orifice 7 cm.; shows some fibrous thickening along the base of the leaflets, the line of closure being normal. Aorta: nodular yellowish thickenings, and a certain amount of branching contractions like the willow-tree type of sclerosis.* Coronary arteries: except at the origin are normal.

MICROSCOPIC DIAGNOSIS: *Chronic interstitial myocarditis.* The muscle shows well-marked striae, and not much pigment about the nuclei. The fibers, especially on cross-section, are much shrunken from the sarcolemma, and occasionally extensive areas with large rectangular nuclei are found. Interstitial tissue is diffusely thickened, especially about the blood-vessels, whose walls are also thickened. At the edges of the fibrosed areas the muscle-fibers are often vacuolated, while others are small and shrunken, having lost their striae. The process is more advanced and extensive in the *papillary muscles* than in the ventricular wall. Sections of the mitral valve show that both the *ventricular and the auricular endocardium are thickened,* especially the former. In some areas the endothelial layer is broken, and fibrous tissue directly continuous with the adherent masses of fibrin is seen, which occasionally includes red and white blood-cells. There is considerable coarse fibrous tissue between the two endocardial layers.

Fig. 42.

nution in the size of the cavities; (3) eccentric enlargement, with enlargement in the size of the cavities (also spoken of as hypertrophic dilatation). The second type, regarding the existence of which there is some difference of opinion, may be simulated if death occurs during systole. (See Figs. 43, 44, 45.) In such a case prolonged immersion in water will bring about a relaxation of the heart muscle.

Pathogenesis.—Excessive demand for work on the part of the heart calls forth the latent reserve force which every normal heart possesses, and which represents the surplus energy which has been stored up under periods of rest. When the demand for increased work becomes constant, hypertrophic changes are brought about. If the demands exceed the limit of the field of response, or the nutritional possibilities, dilatation occurs.

As has been intimated above, the term "concentric hypertrophy" is justly falling into disuse because there is no actual diminution in the size of the chambers in such cases. When hypertrophy is due to an obstruction to the outflow of blood, simple hypertrophy is induced; when it arises from diastolic overfilling, hypertrophy and dilatation occur. This does not result from mere stretching of the muscle-fibers (because even with increased diastolic filling there is no increase in muscular tension), but owing to the fundamental attribute of the heart muscle, by virtue of which every contraction is maximal. Although the contraction time is prolonged when obstruction to outflow or increased diastolic filling occur, this increase is not in proportion to the amount of the hindrance or of the overfilling imposed (Romberg).

Hypertrophy affects only such parts of the heart muscle as are actually called upon to do extra work. An associated or sympathetic hypertrophy, or one due merely to increased nutritional advantages, is never found (Romberg). Atrophy and hypertrophy of different chambers of the same heart are often encountered, as has been shown by Hirsch. Hypertrophy of the

FIG. 43.—VERTICAL SECTION OF THE THORAX. (See also Fig. 44.)

Figs. 43 and 44 show what appears to be a most extraordinary *concentric hypertrophy of the left ventricle.* The walls of this chamber are enormously thickened and the chamber itself almost obliterated as the result of it. This specimen was found among the anatomic material at the University of Pennsylvania. Nothing is known regarding the history of the individual, but it is inconceivable that such an extreme concentric hypertrophy should have developed without more adequate cause than is demonstrable. The aorta above the valves shows the results of a syphilitic aortitis, but the valves themselves are only moderately thickened. We have assumed, therefore, that an explanation must be sought in the fact that the heart ceased acting in systole. (Sections prepared by Dr. George Fetterolf.)

conducting fibers—auriculo-ventricular bundle, etc.—does not occur (Aschoff and Tawara).[1]

The mechanism by which hypertrophy is produced probably varies; the most important being that due to increased intra-cardiac pressure. This factor normally acts as a stimulus to contraction, as has been shown by v. Frey.[2] Before birth the walls of the two ventricles are of equal thickness, but afterward, when much greater work is demanded of the left ventricle, its walls become much thicker than those of the right. That this pressure or stretching hypertrophy is independent of nervous influences seems likely from the investigations of Rieder.[3]

A considerable number of cases of hypertrophy are due to chemical factors. In this group are included adrenalin, and metabolic products of more or less undetermined composition, such as occur in renal disease and intestinal autointoxication.

As opposed to a mechanical origin of cardiac hypertrophy we have the "irritation" hypothesis of v. Dusch, it being assumed that increase of intracardiac pressure by stimulation of the cardiac nerves and ganglia produces an increased force of contraction, and this in turn hypertrophy.[4]

Still another non-chemical explanation has been offered by Albrecht,[5] who discards the internal pressure or nervous hypothesis as untenable, and regards hypertrophy as the result of a chronic proliferative myocarditis—an inflammatory hyperplasia—which exists not as an isolated manifestation, but as an attribute of a chronic process which is often associated with, it may be, nephritis, valvular disease, etc. Other varieties of hypertrophy not explainable on this basis are assumed to result from chemical and bacterial and metabolic toxins.

[1] This statement is also corroborated by Moenkeberg, " Untersuchungen ü. d. Atrio-ventrikular Bündel im menschlichen Herzen," 1909.

[2] Frey: Deut. Arch. f. klin. Med., 1889, xlvi, p. 398.

[3] Rieder: Arch. f. klin. Med., 1895.

[4] Asch: Zur Hypertrophie d. Quergestreiften Muskeln, speziel des Herzmuskels, Berlin, 1906.

[5] Albrecht: Der Herzmuskel u. s. Bedeutung f. Physiol., Pathol. u. Klinik d. Herzens, Berlin, 1903.
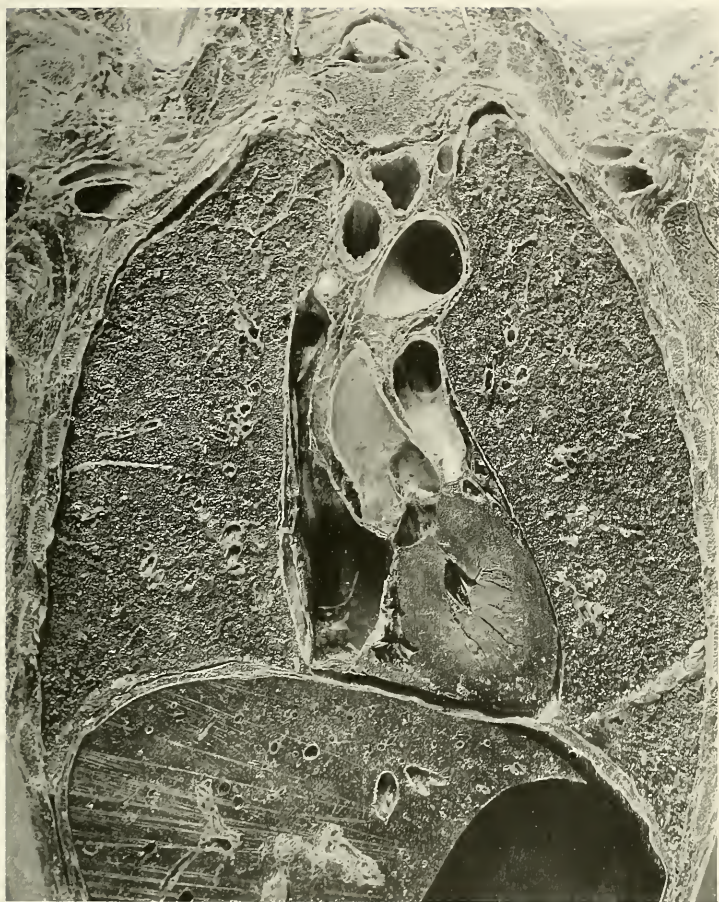
Fig. 44.—Vertical Section of the Thorax. (See descriptive legend for Fig. 43.)

It has been found that chronic nephritis with hypertension is very frequently associated with enlargement of the suprarenal gland,[1] and, further, that in some cases an abnormally large amount of the secretion of this gland can be demonstrated in the circulating blood. Again, it appears that removal of the suprarenals produces a fall of blood-pressure, and that the serum of dogs thus treated has a hypotensive action.[2]

Finally, nervous factors are probably responsible for hypertrophy in a certain number of cases. Thus, for instance, neurotic individuals with a permanently rapid pulse-rate often develop minor grades of hypertrophy.

While cardiac hypertrophy is most common in the subjects of aortic disease, of interstitial nephritis, and in the sons of heavy toil, it is by no means a negligible factor exclusive of the just mentioned conditions. Lubenau[3] in the sanatorium for heart diseases at Beelitz, from which valvular diseases are excluded, found that 40 per cent. of the admissions were on account of "idiopathic hypertrophy," 35 per cent. were cardiac neuroses, and 10 per cent. primary cardiac weakness.

When the left ventricle is hypertrophied, the arterial system is subjected to violent alterations in pressure, which produce minute ruptures in the vascular coats; this leads to fibrosis, and ultimately to an arteriosclerosis, which in turn demands a greater hypertrophy, and thus a vicious circle is established.

Since increased work on the part of the heart produces hypertrophy, animals which are fleet of foot—deers, hares—have larger hearts than less active animals of an equal size. The wild rabbit has a larger heart than his tame cousin. The same law holds good for birds of long flight.[4] Animals of the same size and breed which are forced to exercise, develop larger hearts than the controls which are prevented from exercising.[5] We also know that not only the left, but also the right ventricle hypertrophies in these cases, due apparently to increased pressure in the pulmonary circulation during exercise, since it has been shown that activity produces a physiologic emphysema, and this in turn increases tension in the pulmonary capillaries. Athletes, especially those accustomed to prolonged contests, such as rowing, bicycling,[6] and long-distance running, generally develop more or less hypertrophy. They are said to be two and one-half times as subject to cardiac diseases as other people.[7] Participation in record-breaking feats has been shown to be especially harmful.[8]

[1] Philpot: Quart. Jour. Med., Oct., 1909.
[2] Reneau: Thèse de Lyon, 1909.
[3] Lubenau: Zeit. f. klin. Med., 1906, lx, p. 134.
[4] Grober: Deut. Arch. f. klin. Med., 1907, xci, p. 502.
[5] Kulbs: Münch. Kongr. f. inn. Med., April, 1906.
[6] Shieffer: Deut. Arch. f. klin. Med., lxxxix, 604.
[7] Hutchinson, quoted Davy: Lancet, Feb. 16, 1907.
[8] Selig: Mediz. Klinik, March 29, 1908.

FIG. 45.—CARDIAC HYPERTROPHY.

A specimen from the Museum of the University of Pennsylvania, illustrating the type known as "concentric hypertrophy." The wall of the left ventricle shows an enormous degree of thickening; the cavity has apparently not enlarged in proportion. The aorta shows well-marked atheroma and calcification about the sinus of Valsalva.

A hypertrophied heart is never as efficient as a normal organ, because associated with its increase in size there has been no corresponding increase in the size or number of its ganglion-cells, nerve-cells, or nutritional possibilities. Although the existence of a pure "work hypertrophy" may be accepted as proved, despite the denial of its existence by some well-known clinicians, nevertheless hypertrophies of this sort never attain the enormous dimensions which are met with in the hypertrophy of disease. An increase of 50 odd per cent. may be produced by the former, and an increase of 200 or 300 per cent. may occur in the latter. Thus, some enormous hypertrophies have been recorded—1300 gm. (Jackson[1]), 1700 gm. (Osler), 2500 gm. (Norristown Hospital). Among 32 arteriosclerotic hearts studied by Jackson, only 4 weighed less than 400 gm.

Great cardiac enlargement naturally takes up considerable intrathoracic space. When there is insufficient room, we see bulging of the precordial ribs and compression of the lungs. How great this compression may be, is shown in a case at the Philadelphia Hospital in the service of Dr. Lloyd, in which actual erosion of the thoracic vertebræ was thus produced.[2] Lack of space, if of sufficient degree, may mechanically interfere with heart action and be the direct cause of cardiac symptoms. This fact has been especially dwelt upon by Herz.[3]

[1] Jackson: Boston Med. and Surg. Jour., 1896.

[2] Philadelphia Hospital Autopsy Records, vol. x, p. 17.   (April 4, 1897.)

[3] Herz: Wien. med. Woch., 1908, xxxiii, 397.

Fig. 46.—Sagittal Section of the Thorax. (See also Figs. 47 and 48.)

Figs. 46, 47, and 48 demonstrate how little room for expansion there is for the heart between the vertebral column, and the anterior thoracic wall. Displacement to the right is impracticable, since the antero-posterior thoracic dimensions are smallest in the median line. Movement to the left is hindered by the increasing convexity of the ribs. If any displacement takes place, therefore, it must be backward and downward. When the possibility of motion in these directions is exhausted, a squeezing of the heart must occur. It is plainly evident that such a state of crowding, whether it results from enlargement of the heart or of the lungs (pericardial effusion) or from deformity of the chest—empyema, etc.—must have a deleterious effect not only on the functionation but also upon the nutrition of the heart. The most striking effects which result from diminished intrathoracic space are noted in cases of valvular insufficiency, especially when associated with dilatation and myocarditis (Herz). (Sections from the Laboratory of Anatomy of the University of Pennsylvania, Dr. George Fetterolf.)

Right pulmonary artery

Left superior pulmon-
ary vein
Left auricular appendix
Left inf. pulm. vein

Left auricle

Mitral valve (anterior
leaflet)

Aorta

Aortic leaflets

Left ventricle
Right ventricle
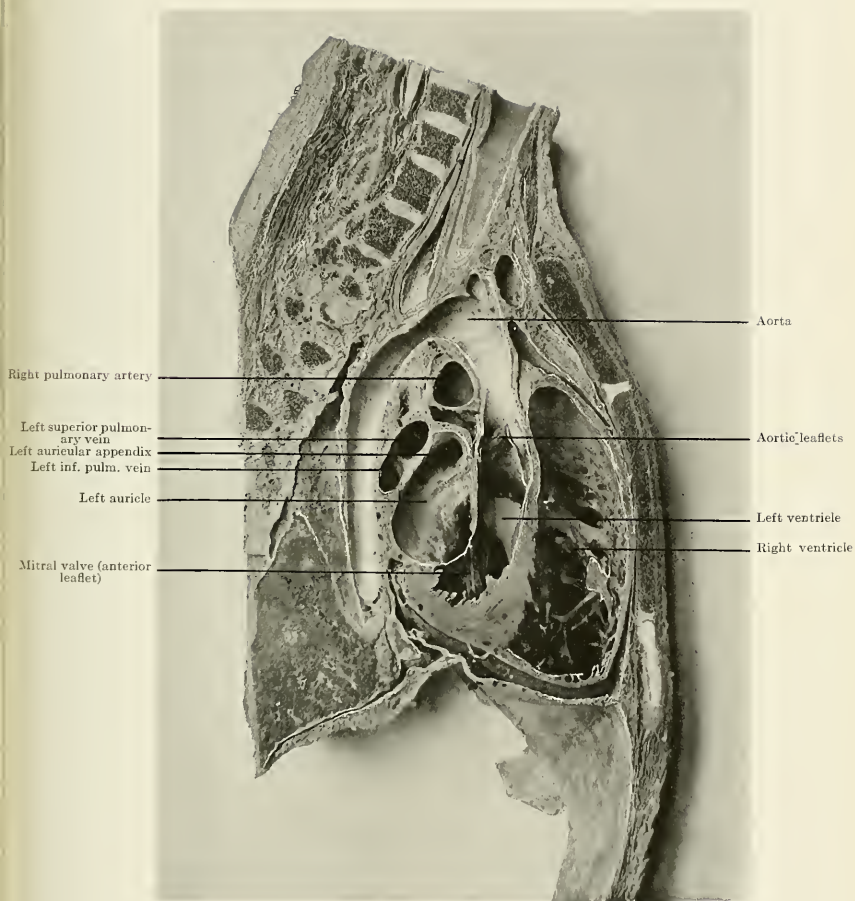
Fig. 46.

Probably a part of the dyspnea seen in high grades of pulmonary emphysema is due to this crowding of the heart. The great lessening of dyspnea in cardiac patients by the simple procedure of propping them up in bed, so that with lowering of the diaphragm the heart is afforded more room, is another example of the importance of external pressure.

This is well illustrated in Figs. 43 and 44, a glance at which will show how snugly the heart is fitted in between the lungs and diaphragm.[1]

Exclusive of valvular lesions, *chronic nephritis* is perhaps the most frequent cause of cardiac hypertrophy. The exact *modus operandi* by virtue of which it occurs is still unsettled. In many cases arterial hypertension seems to be accountable for the condition, but this factor, while usually, is not invariably, present. Then, again, we have still to learn the cause of such hypertension, whether it is reflex or toxic, whether it is due to arteriosclerosis, especially of the splanchnics or the renal arteries; whether it is due to overactivity of the adrenals, and if so, why such an oversecretion occurs. The hypertrophic changes are apparently closely associated with contraction of the smaller arteries, which, in turn, seems to be due to a toxic factor.

The importance of arteriosclerosis or constriction of the splanchnic area as a cause of hypertension and cardiac hypertrophy, which was prominently brought to the fore through the investigations of Hasenfeld[2] and Hirsch,[3] and widely accepted, has apparently been overestimated. Marchand,[4] as well as Longcope and McClintock,[5] were unable to corroborate the above-mentioned observations. Neither experimentally or at autopsy could the last-mentioned investigators find any definite association between cardiac hypertrophy and sclerosis of the abdominal aorta or the splanchnic vascular domain.

Cystic kidneys and hydronephrosis are often associated with

[1] These sections were prepared by Dr. George Fetterolf.
[2] Hasenfeld: Deut. Arch. f. klin. Med., 1897, p. 193.
[3] Hirsch: Ibid., 1899, p. 579.
[4] Marchand: Verhandl. d. Kong. f. inn. Med., 1904, p. 60.
[5] Longcope and McClintock: Arch. Int. Med., 1910, p. 439.

Vena azygos major

Right bronchus

Right pulmon-
ary artery

Fossa ovalis

Left auricle

Inferior vena cava

Superior vena cava

Right auricle

Coronary sinus

Tricuspid valve

Pericardium

Hepatic vein

Fig. 47.—Sagittal Section of the Thorax. (See descriptive legend under Fig. 46.)

cardiac hypertrophy. Myocardial changes and disease of the coronary arteries are often relatively slight in nephritis, and death from heart failure is more frequent in secondary than in primary nephritis.[1]

It was formerly taught that the hypertrophy which occurs in chronic nephritis, and even in acute nephritis if its duration exceeds four weeks,[2] affected chiefly, if not entirely, the left ventricle. Careful examinations by Müller's method have shown that all the cardiac chambers are affected[3] in 82 per cent. of the cases. It is true, however, that the left ventricle shows the most pronounced changes, and that right-sided enlargement appears to be definitely a sequel (Paessler). The hypertrophy is generally regarded as due to increased work of the left ventricle in over coming abnormal resistance. With a normal blood-pressure the heart handles about 10 pounds of blood per minute, and with hypertension this work may readily be doubled. The nephritis in which interstitial changes preponderate is the type in which cardiac hypertrophy most frequently occurs, although cases of this type are sometimes seen without either hypertension or cardiac hypertrophy. Some cases of diffuse nephritis are ac companied by hypertrophy, although this is unusual. Hypertrophy is said never to occur in amyloid renal disease. It may, according to Cohnheim, follow obstruction of the ureter.

The interrelationship between disease of the heart, the arteries, and the kidneys has been a fertile topic of discussion. It has been explained: (a) as part of a general process; (b) by the fact that disease of the kidneys produced an increased blood-pressure reflexly, this being nature's compensatory method of maintaining an adequate urinary output; (c) by assuming that the heart lesion produces the renal lesion by means of hypostatic congestion. The occurrence of combined disease is very common.

[1] Friedländer: Arch. f. Physiol., 1881, p. 168.
[2] Hasenfeld: Arch. f. klin. Med., lix, 210.
[3] Scheel: Ugeskrift f. Laegevidenskaben, Aug., 1909, lxxi.

Left innominate
vein

Right pulmonary
artery
Descending aorta
Left bronchus

Left auricle

Papillary muscle

Aortic valves

Right ventricle
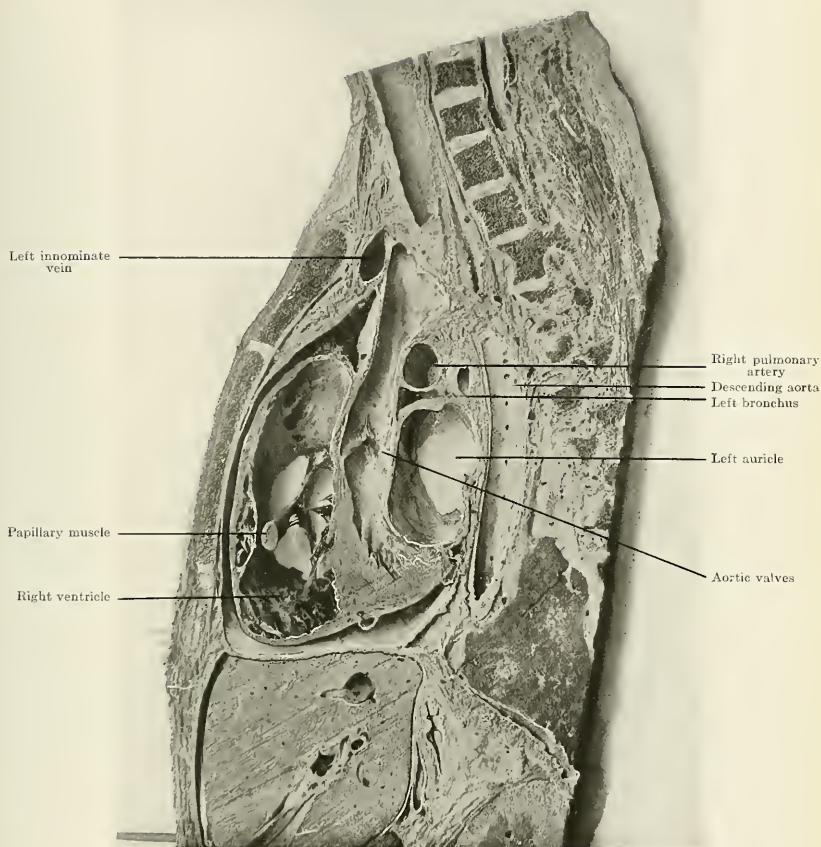
FIG. 48.—SAGITTAL SECTION OF THE THORAX. (See descriptive legend under Fig. 46.)

This figure illustrates: (1) the too often insufficiently appreciated posterior position of the left auricle, (2) the comparatively fixed and unyielding structures by which it is surrounded: the descending aorta, esophagus, and spinal column behind; the left ventricle and diaphragm below; the left ventricle and right auricle in front. When dilatation of the left auricle occurs it must be upward mainly. (3) It is also evident that direct pressure from the auricle upon the aortic arch is, on account of the intervening structures—the pulmonary arteries, veins and the left bronchus—impossible. (See also the Figs. 46 and 47, and compare text, page 70.)

Among 165 autopsies on cases of cardiac and aortic disease at Warsaw, the kidneys were normal in only 6. Fifty-four were cases of mitral, and 50 of aortic disease.[1] In 66 cases of chronic interstitial nephritis the left ventricle was hypertrophied in 30.5 per cent.; normal or atrophied in 58 per cent.; both ventricles hypertrophied in 11.5 per cent. In 22 cases of arteriosclerosis the left ventricle was hypertrophied in 27 per cent.; right and left ventricles hypertrophied in 9 per cent.; normal in 64 per cent. In 25 cases of parenchymatous nephritis the left ventricle was hypertrophied in 12 per cent.; right and left ventricles hypertrophied in 4 per cent.; normal in 84 per cent.

Cohnheim's explanation of the cardiac hypertrophy in nephritis was based on mechanical grounds. He attributed the rise of blood-pressure to diminution in the size of the renal capillaries resulting from interstitial nephritis. But Alwen[2] was unable to produce any considerable degree of hypertension by renal compression. Furthermore, Heinike and Paessler's[3] progressive resection of the kidneys did not prove that the increased arterial pressure was not toxic, rather than mechanical. Finally, Jores[4] found less actual destruction of capillaries in the red granular kidney than in the atrophic kidneys of late parenchymatous nephritis, and in amyloid disease, in both of which conditions arterial hypertension is infrequent. Schur and Wiesel,[5] on the other hand, found a constantly increased amount of adrenalin in the blood of nephritics, and believe that the high blood-pressure results from stimulation of the medullary portion of the adrenal glands. These experiments have, however, not been corroborated by others.[6] Pearce[7] has described a nephrotoxic substance in the blood of dogs in which nephritis had been produced, which when injected into normal dogs produces the urinary evidence of nephritis. The evidence thus far, then, indicates a chemical rather than a mechanical origin of the arterial hypertension of nephritis.

Reicher[8] has shown that in experimental nephritis produced by cold, adrenalin is found in increased amounts in the blood immediately succeeding the cold bath, indicating that perhaps this substance is the cause of the hypertension in the early stages of the natural disease.

Hypertrophy in Valvular Disease.—The myocardial changes which follow experimental section of the aortic and tricuspid valves indicate a mechanical and not an inflammatory origin. The primary dilatation which follows the operation produces first

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[1] Bronowski: Presse Médicale, 1904, No. 99.

[2] Alwen: Deut. Arch. f. klin. Med., xcviii, 137.

[3] Heinike and Paessler: Verhandl. d. deutsch. path. Gesellsch., 1905, p. 99.

[4] Jores: Verhandl. d. deutsch. path. Gesellsch., 1908, p. 187.

[5] Schur and Wiesel: Verhandl. d. deutsch. path. Gesellsch., 1907, p. 175.

[6] Aschoff and Cohn: Verhandl. d. deutsch. path. Gesellsch., 1908, p. 31. Goldschmidt: Deut. Arch. f. klin. Med., xcix, 186.

[7] Pearce: Jour. Med. Research, 1908, 2.

[8] Reicher: Berlin. klin. Woch., 1908, No. 31.
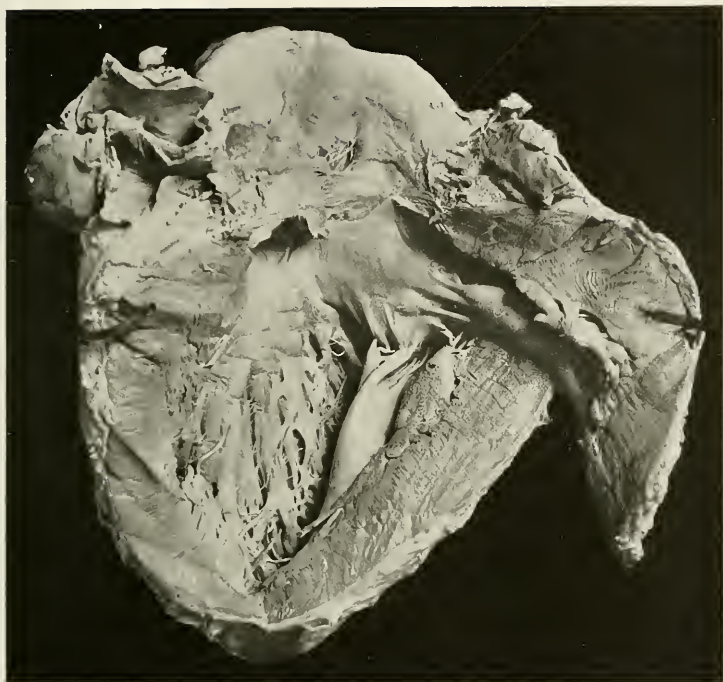
Fig. 49.—Left Ventricular Hypertrohpy.

A case of aortic and mitral stenosis. The aortic valves have unfortunately been destroyed through handling. *The mitral valve shows marked induration of the leaflets and chordæ tendineæ, together with a few old fibrous vegetations. The papillary muscles are hypertrophied.* (Specimen from the German Hospital, Philadelphia.)

an increase of connective tissue, later a muscular hypertrophy. These changes may occur independently of each other.[1] This is opposed to the older teaching of Albrecht, whose views were based upon a study of human hearts, mostly in cases of nephritis, in which condition serositis and other inflammatory changes are common. Tangl[2] has shown that even in the most emaciated animals hypertrophy of the left ventricle will develop after artificially produced valvular lesions.

Hypertrophy is a result of the prolonged overexertion of the heart muscle which is required to supply the demands of some abnormal condition of the circulation. It is the result of cardiac compensation under these conditions, not the cause of it. The experimental section of an aortic valve is followed by dilatation of the ventricle, and almost equally soon a dilatation of the auricle, together with a mitral systolic murmur. There is no faltering of the circulation; the animals are active and playful and apparently never suffer from edema or dyspnea; all of which facts show that a normal myocardium is instantly able to do an enormously increased amount of work without being prepared for it by any process of hypertrophy. Even in long-standing experimental lesions there do not seem to be produced any of those chronic myocardial changes which we find in human hearts.

Schnackers[3] found that even when domestic animals develop endocarditis by natural channels of infection, these lesions are not followed by myocardial changes at all comparable to those which occur in human beings. The Purkinje fibers, on the other hand, seem to be seriously damaged.

Hypertrophied hearts of large dimensions are also met with as a result of excessive beer-drinking over prolonged periods— "beer heart," "Munich heart." This lesion results not so much from any poisonous effect of the beer, but from an increased

[1] Stadler: Deut. Arch. f. klin. Med., Aug., 1907, xci.
[2] Virchow's Archiv, cxvi, 432.
[3] Schnackers: Frankfurter Zeit. f. Path., 1909, p. 658.

FIG. 50.—HYPERTROPHY AND DILATATION OF THE LEFT VENTRICLE.

The mitral valve shows numerous old inflammatory vegetations, with more or less destruction of tissue. The left auricular wall is attenuated and its cavity enlarged. (Specimen from the Episcopal Hospital, Philadelphia.)

artificial plethora caused by the ingestion of excessive quantities of fluid, which in turn necessitates an increased systolic output.

The left ventricle is hypertrophied in cases of aortic aneurism only if there is an insufficiency of the aortic valves.

"*Idiopathic hypertrophy*" has been reported as occurring even in infancy. Some of these cases occurred in nurslings. All sorts of explanations have been offered, from Virchow's suggestion that we were dealing with a diffuse form of rhabdomyoma, to Michaud's belief that the chromaffin system is at fault.[1] The majority of the cases, however, occur in the fourth or fifth decade of life. More or less constant arterial hypertension is generally present, which cannot be satisfactorily explained by the urinary examination. Not infrequently such cases terminate after the manner of nephritics. The hypertension seems to be in part the result of metabolic toxemia, and in part the result of adrenal overactivity, and until the relationship between these conditions and chronic interstitial nephritis is better understood we can hardly expect definite knowledge concerning this so-called "idiopathic hypertrophy."

Many of the discordant reports which have from time to time appeared in medical literature regarding the presence or absence of hypertrophy of certain heart chambers have been due to inexact methods. The most satisfactory, although a time-consuming, method of determining this question is known as "*Müller's method*," which consists of careful weighing of the separated heart chambers after the blood-clots, excess fat, etc., have been removed. This is much more satisfactory than measurement, since with the latter procedure marked variations occur which depend on whether the heart has ceased to contract in systole or in diastole.

The question as to *why a hypertrophied heart fails in compensation* has not been definitely settled. Krehl regards it as due to a progressive myocarditis.

[1] References to this subject together with a criticism of the cases reported in the literature will be found in Hedinger's article, Virchow's Archiv, vol. cxxviii, 1904, and in that of Michaud, Correspondenzbl. f. Schweitz. Aerzte, 1906, p. 779.
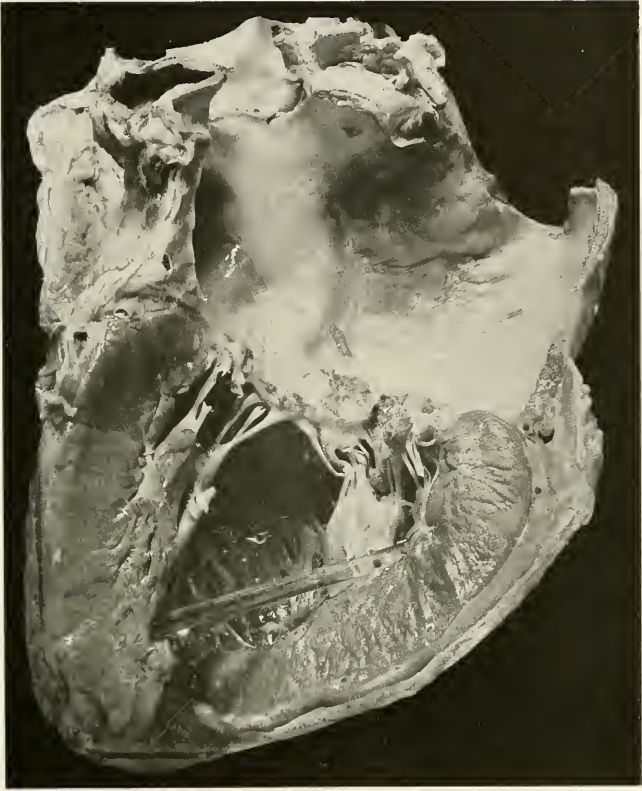
FIG. 51.—HYPERTROPHY AND DILATATION OF THE LEFT VENTRICLE.

Chronic mitral and aortic endocarditis. The left ventricular wall is enormously thickened and the cavity enlarged. The mitral valve shows extensive sclerosis. Many of the chordæ tendineæ have ruptured; the rest are thickened and contracted. Numerous old sclerotic elevated patches are seen on the auricular surface of the mitral leaflets—the remnants of a former endocarditis. The papillary muscles are hypertrophied and the left auricle is dilated. (Specimen from the Philadelphia Hospital.)

On the other hand, the careful researches of Aschoff and Tawara failed to find such changes sufficiently constant to account for the condition. So, too, the studies of Lissauer[1] fail to decide the question as to whether the cardiac paralysis results from a progressively increasing demand upon the heart muscle, or from lesions in the nervous mechanism.

A chemical explanation of the cause of myocardial weakness has been offered by Rzentkowski, who found that the myocardium of the left ventricle from cases dying of prolonged illness, but without actual cardiac disease, contained more proteid, fat, glycogen, etc., and much less sodium chlorid than the right ventricle. He has endeavored to explain heart failure by an insufficiency of these substances, or by disturbances in their distribution or in their utilizability.[2]

Bence, on the other hand, found that neither hypertrophy nor exhaustion of a heart chamber was associated with any abnormality in the distribution of nitrogen in the heart muscle, and, further, that in normal and simple hypertrophied hearts the proportion of nitrogen bore a constant relation to weight. During exhaustion the relation between muscular weight and nitrogen content departs from the normal, inasmuch as the fixed nitrogen becomes proportionately less.[3]

Merkel[4] suggests that stasis in the coronary veins plays a rôle in preventing a removal of waste products, especially since this blood is not carried off by collateral circulations. Pratt[5] failed to find sufficient fatty change to account for it, and Faverges'[6] investigations indicated that the austere prognosis in fatty degeneration was very much overrated. Aschoff was unable to find the interstitial changes in either muscle-, nerve-, or ganglion-cell which Daddi[7] had described. Merkel and Jannin[8] have demonstrated by means of injection of the coronary arteries the fact that in cases of left ventricular hypertrophy there is an enormous increase in the vascular supply which is given off from the left artery, and, further, the fact that the right and left coronary arteries anastomose both as arterioles and as capillaries, and that anastomotic branches from the pericardium to the heart exist. In some cases, of course, the hypertrophy fails as the result of those changes which are associated with advancing years. It also fails in many cases because the pathologic changes in other organs with which it is associated are progressive and have a direct physiologic as well as anatomic relation to it. For the present we must conclude that *the insufficiency of hypertrophy rests upon a variable basis*, and that although some cases can be explained upon anatomic grounds, in others we have to assume a physico-chemical or functional basis. The rôle of the vasomotor system is, as it is in infectious diseases, more important than is generally recognized.

[1] Lissauer: Münch. med. Woch., 1909, No. 36.
[2] Zent. f. klin. Med., 1910, lxx, 337.
[3] Zeit. f. klin. Med., lxvi, Nos. 5 and 6.
[4] Merkel: Münch. med. Woch., 1907, p. 753.
[5] Pratt: Quoted Zentralb. f. path. Anat., 1905, p. 531.
[6] Faverges: Wien. klin. Woch., 1905, No. 19.
[7] Daddi: Zentralb. f. inn. Med., 1904, p. 119.
[8] Merkel and Jannin: Centralb. f. allg. Path. u. path. Anat., 1907, xvii, 876.
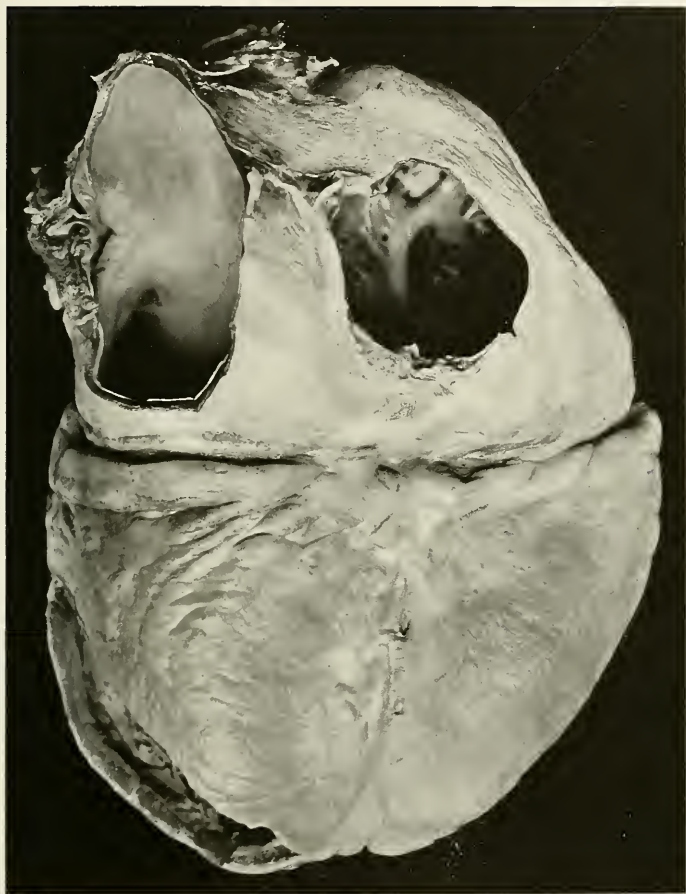
FIG. 52.—CARDIAC DILATATION.

The heart is large and flabby, its walls thinned. Its form is somewhat quadrangular.
(Photograph by Dr. Alfred R. Allen.)

In a study of the cause of compensatory failure in 34 cases of hypertrophy, Schlüter[1] found fatty degeneration of the muscle-fibers relatively frequently, together with enlargement and distortion of the nuclei. Connective-tissue or round-cell infiltration was less common and more localized. He believes that these manifestations are not the anatomic expression of heart weakness, but the results of insufficient cardiac activity—slowed circulation and lymphatic stasis. Insufficiency of the hypertrophied ventricle is the result of inadequate reserve power, which he attributes rather to diminished excitability than to actual muscular disease.

[1] R. Schlüter: Die Erlahmung des hypertrophieten Herzmuskels, Vienna, 1906.

FIG. 53.—HYPERTROPHY AND DILATATION OF THE HEART.

W. B. (Philadelphia Hospital. November 28, 1901. xiii: 103. Pathologist: Dr. Prince.)

PATHOLOGIC DIAGNOSIS: Myocarditis; bilateral pleural effusion; *hypertrophy and dilatation of the heart;* mitral insufficiency; aortic stenosis; advanced arteriosclerosis; edema of the lungs; acute nephritis.

Pericardium: Contains 100 c.c. of fluid.

HEART: *Weighs 760 gm. The muscle is pale, the walls friable. The left ventricle averages 1.5 cm. in thickness. The aortic valves are incompetent, their edges thickened and indurated. The mitral ring admits five fingers; its valve leaflets are slightly thickened. The aorta is practically one mass of atheromatous plates, with excavations. The left ventricular cavity shows many calcareous plates, and is about twice the normal size.*
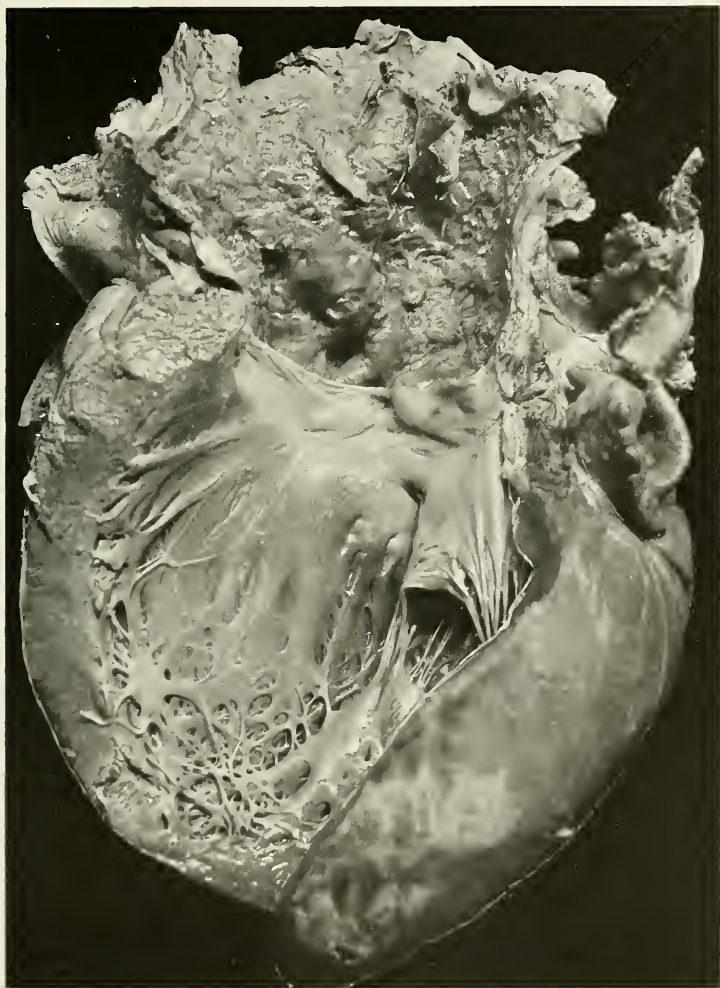
FIG. 53.

X. CARDIAC DILATATION

Pathogenesis.—By dilatation of the heart we mean an increase in the size of its chambers, which results from stretching of its muscular walls. Such a condition may occur acutely under sudden, prolonged, or excessive strain, especially in subjects out of training, or as the result of toxic processes, such as diphtheria, typhoid fever, pneumonia, also as the result of prolonged nervous strain and sudden mental or moral shock. The emotional stress acts on the vasomotor nerves, the arterial spasm inducing a hypertension which reacts on the myocardium. It has also been suggested that the moral shock has further a direct action on the centers regulating the innervation of the heart. Such cases were observed among the Jews during the massacres in Odessa.[1] Chronic dilatation of the heart is generally associated with or a sequel of hypertrophy. It is usually due to two factors: inadequate nutrition and increased endocardial pressure, such as occurs in the gradual occlusion of sclerotic coronary arteries, together with valvular disease and an increased demand for hypertrophy. Increased endocardial pressure may result not only from diminished outflow, but also from increased inflow—from a rise of venous pressure.

When extra work is suddenly required of the ventricle, as, for instance, if the aorta is clamped, there first results a dilatation of the chamber associated with a diminution of the systolic output; following this in healthy hearts there occurs as the result of increased tonicity an increase of the systolic output, so that the ventricle again empties itself properly. But if the heart is unable to meet the emergency, or the obstructive force is too great, dilatation ensues (O. Frank, Hirschfelder).

From what has been said it will be readily understood that, as seen at autopsy, dilatation of the heart is generally associated

[1] Cheinisse: Semaine Médic., 1907, xxvii, No. 9.

FIG. 54.—AN EXTREME GRADE OF SCLEROSIS AND CALCIFICATION OF THE AORTIC VALVES AND OF THE AORTA ITSELF.

The valves are shrunken, thickened, stiffened, and show calcareous change; the aorta is dilated and consists of great masses of calcareous infiltration, for the purpose of showing which the vessel has been everted. The mitral valve is sclerotic. The aortic valves are calcified, the ventricular endocardium is thickened, and the left ventricle is hypertrophied and dilated. The aorta shows as saccular aneurismal dilatation. (Specimen from the Philadelphia Hospital.)

with more or less hypertrophy, in those cases in which the causative factors have been of prolonged duration.

Simple dilatation without a preceding hypertrophy may result from the toxemia of infectious disease, especially diphtheria, from metabolic poison, as in uremia, from lack of nutrition or the ingestion of poison, or from sudden exertion, and apparently at times from psychic shock.[1]

There can hardly be a doubt that toxins play an extremely important rôle in the production of dilatation. The microscopic examinations by Tawara on the hearts of patients dead of cardiac failure in a large number of cases showed no changes which could account for death. The sudden death in infections such as diphtheria is an example. In diphtheria this sudden death is usually attributed to toxic action on the vagus, inasmuch as it is often associated with unexplained and sudden vomiting, and since post-diphtheritic paralyses are well known. So, too, the question has been brought up whether diphtheria does not more or less often irreparably damage the heart so that sudden death may occur months, or even years, after the original infection.

Morbid Anatomy.—The heart, in addition to being enlarged, is relaxed, flabby, and distended with blood. Dilatation generally affects chiefly the right side. The auriculo-ventricular orifices are enlarged, the septa may bulge toward the less affected side, while chronic myocardial changes of a fatty or fibroid nature are more or less evident. (See Fig. 52.)

It is doubtful if all cases of cardiac dilatation could be explained on an anatomic basis, even if our methods of examination

[1] Two cases reported by Marmorstein, Wien. med. Woch., Aug. 4, 1906. Starck: Münch. med. Woch., 1905, lii, No. 7.

FIG. 55.—CALCIFICATION OF THE AORTA.

Specimen showing the left ventricular cavity. The aortic valves are thickened, slightly retracted, and contain calcareous deposits. The aorta is greatly thickened and its entire surface is covered with white and dark yellow, roughened and projecting calcareous plates. (Yellow being a relatively non-actinic color, these plates appear as black and brown in the reproduction.) The mitral valve is moderately thickened. (Specimen from the Philadelphia Hospital.)

Fig. 55.

were more searching and exact. Dilatation is essentially the result of diminished muscular tone, and while doubtless many cases can be explained by structural microscopic changes in the muscle-fibers or nerves, yet we know that muscular tone varies greatly within functional limits.

Clinical Considerations.—There has been much discussion and investigation regarding the existence of a functional cardiac dilatation. It was at one time taught that the so-called "second wind" of the well-trained athlete depended upon the appearance of a physiologic dilatation by virtue of which the heart was enabled to handle more blood. The investigations of Dietlen, Moritz, De la Camp,[1] Raab,[2] and others indicate that such is not the case. On the contrary, the normal heart becomes smaller during severe exertion, and when dilatation occurs, we are in all probability dealing with an organ whose reserve power is not up to par.

We must also bear in mind that the normal heart is smaller in the erect than in the recumbent postures, due to the fact that in the former a larger amount of blood is pent up in the vessels below the heart by the action of gravity.[3] It is also possible that, pressure-tension of the pericardium being greater in the standing position, a greater pressure is exerted not only on the heart itself, but also upon the venæ cavæ, both of which would tend to lessen the blood-content of the heart, as would also lowering of blood-pressure and increase of pulse-rate.

Dilatation sometimes results from pure fatigue of the muscle, no structural changes being demonstrable. Dilatation by bulging of the ventricle drags on the papillary muscles and makes it more difficult for the auriculo-ventricular valves to close, thus producing valvular incompetency.

Although the consideration of *myocarditis* properly belongs to a work which concerns itself with microscopic pathology, yet the subject is so intimately associated with the conditions which we have discussed that a brief allusion to certain phases seems warranted.

Acute myocarditis may occur as a result of infectious processes

[1] De la Camp: Zeit. f. klin. Med., vol. li.
[2] Raab: Münch. med. Woch., 1909, No. 11.
[3] Dietlen: Habilitationsschrifft, 1909.
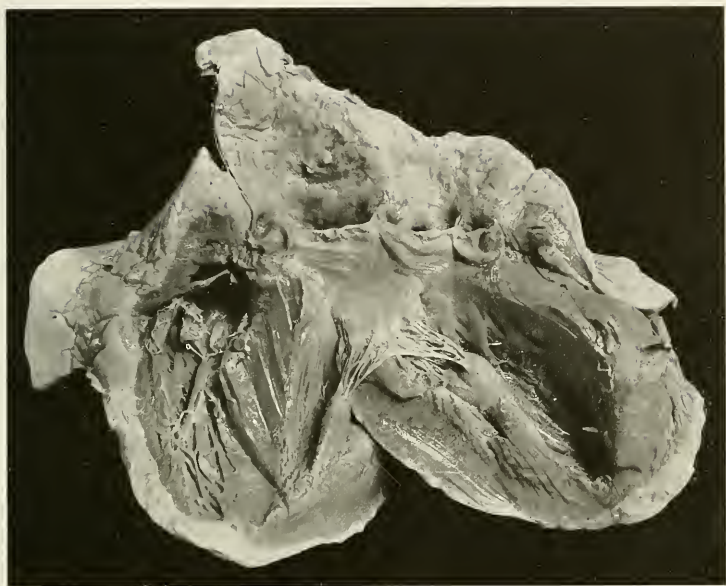
FIG. 56.—CALCIFICATION OF THE AORTA.

The entire aorta is one hard, brittle, rough, thickened, calcareous mass, which fractures with an audible snap when the vessel is flexed. The aortic valves share in this process of calcification. The wall of the left ventricle is greatly thickened. The pericardium is thickened and the subpericardial fat increased in amount. (Specimen from the German Hospital, Philadelphia.)

either as the result of micro-organismal or toxic action. It is met with more especially in diphtheria, typhoid and typhus fevers, rheumatic fever, scarlatina, and influenza. Embolic and thrombotic affections of the coronary vessels, and septic processes, may also be causative factors. The toxemia of pregnancy, especially when eclampsia has occurred, often causes myocardial degeneration.

Chronic myocarditis is often the result of poor cardiac nutrition, which, in turn, means that the coronary circulation has in some way been rendered inadequate. Thus, sclerosis of these vessels leads to fibroid or fatty changes according to the amount of vascular damage. Again, valvular lesions, especially aortic obstruction, lead to myocarditis, because with an increased demand for cardiac work there is a relative diminution of blood-supply. Coronary sclerosis may arise from conditions similar to those which cause arteriosclerosis elsewhere. We must bear in mind, however, that the mouths of these vessels, arising as they do from the aorta in close proximity to the heart, are often seriously constricted at their point of origin as the result of disease of the aorta, without there being any marked pathologic changes in their later course. It is in this respect especially that *syphilitic aortitis* plays so important a rôle, producing, as it does with great frequency, aortic aneurism, aortic insufficiency, and myocarditis. That this statement does not invariably apply, however, is indicated by the experimental work of Fleisher and Loeb, who found that adrenalin injections, when combined with certain other substances, such as spartein sulfate and caffein sodium benzoate, produce both macroscopic and microscopic myocardial changes.[1]

The direct cause of these lesions seems to be a mechanical one. "The typical seat of the lesion at the base of the left ventricle, where the greatest strain is exerted, favors this theory. Furthermore, analogous conditions have been shown to occur in striated muscle in conditions of overexertion. The fact

[1] Fleisher and Loeb's article, Arch. Int. Med., Feb., 1909, contains also a résumé of the literature concerning experimental myocarditis. See also a second article by the same authors, Arch. Int. Med., Oct. 15, 1910.

FIG. 57.—SCLEROTIC AND CALCIFIED CORONARY ARTERIES.

Specimen from the Museum of the University of Pennsylvania, showing the root of the aorta and the coronary arteries, the myocardium being removed by dissection. The vessels are greatly thickened, and consist of masses of calcareous nodules and plates.

that the injection of spartein and adrenalin into dogs, whose hearts are relatively stronger than those of rabbits, does not cause the appearance of myocardial lesions, adds further support to this theory. These lesions are in all probability not due to lack of nutrition of the muscle-fibers as a result of contraction of the coronary vessels, inasmuch as it has been shown that adrenalin does not cause a contraction of these vessels."

Even small doses of adrenalin in the rabbit produce well-marked myocardial changes, although these lesions show a tendency to heal. Pearce[1] has shown that large quantities of this substance injected into animals may produce sudden death from acute dilatation or from insidious myocardial changes which occur independently of coronary sclerosis.

Bjorksten succeeded in producing myocardial changes in animals by the injection of micro-organisms (bacillus coli, pneumococcus, typhoid bacillus, staphylococcus), and also of their toxins.[2] Similar results were obtained by Arloing and De Lagoanère with streptococci and staphylococci.[3]

Rheumatic myocarditis is etiologically one of the most important varieties. It accompanies most cases of rheumatic endocarditis, and it is to this pathologic process that many cases of cardiac hypertrophy and chronic myocarditis owe their origin. Macroscopically rheumatic myocarditis shows little that is characteristic. Microscopically an inflammatory tissue proliferation which manifests itself as small interstitial nodules is noted. This process spreads to the neighboring muscle-fibers and produces degeneration in them.[4] The hypertrophy and dilatation affects both ventricles, and is often considerable, more so than the microscopic changes seem to account for. Ventricular hypertrophy and dilatation are evidently the result of toxic action. Death in the rheumatic carditis of childhood is generally directly due to the myocardial lesions.[5] The nodules above referred to are by some considered characteristic of rheumatic infection, but they have also been described as occurring in chronic nephritis and in non-rheumatic infections. Rheumatic myocarditis tends to be progressive, a progression which is often considerably enhanced by subsequent reinfections.

[1] Pearce: Albany Med. Annals, Jan., 1907, p. 42.
[2] Bjorksten: Arbeit. path.-anat. Institut Helsingfors, 1908.
[3] Arloing and De Lagoanère: Thèse de Lyon, 1908.
[4] Geipel: Deut. Arch. f. klin. Med., lxxxv, p. 75.
[5] Coombs: Quart. Jour. Med., Oct., 1908, p. 26.
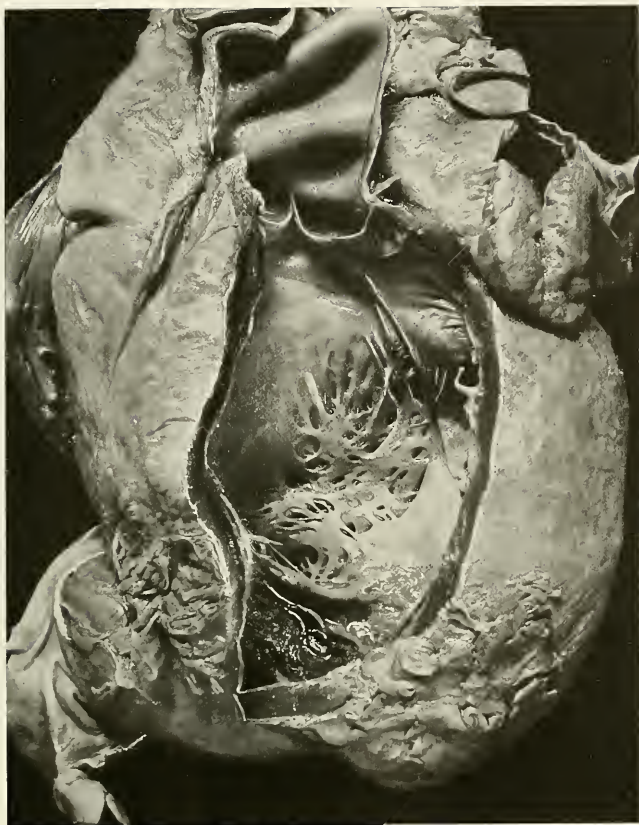
FIG. 58.—CARDIAC ANEURISM.

The lower part of the left ventricle shows a marked protuberance both to the right and to the left of the incision. On the external surface of this bulging area the pericardium is densely adherent. The ventricular wall at this point is thinned and the muscle appears dark and softer than elsewhere. The interior of the sac communicates directly with the left ventricular cavity. At the lowermost end of the incision, part of a dark blood-clot is seen which extends into, and to a certain extent fills, the sac. The left ventricle is hypertrophied and dilated. The aorta shows slight arteriosclerotic change. (Specimen from the Philadelphia Hospital.)

Fig. 59.—Aneurism of the Heart.

J. N., white, male, aged seventy-seven years. (Pennsylvania Hospital. Autopsy No. 425. Pathologist: Dr. Longcope.)

Clinical Notes: Admitted nine days ago, having been ill for two or three weeks, with cough and chilliness. In delirium he had wandered from his bed, to which he was returned only after a tussle. He *died suddenly* two hours later.

Physical Examination: No heart murmurs. First sound faint. Action of heart irregular.

Pathologic Diagnosis: *Aneurism of the heart, with rupture into the pericardium. Occlusion of the descending branch of the left coronary artery.* General arteriosclerosis. Chronic diffuse nephritis.

Pericardium: Is filled with blood.

Heart: *Is much enlarged.* The epicardium is filled with fat, which measures 0.5 cm. in some places. *The organ has a peculiar shape, due to bulging of the left ventricle, so that the heart from apex to base is elongated.* In the bulging tip of the left ventricle there is a rupture 4 cm. in length and 2 cm. in width. The surface of the heart about the tear is mottled deep red and brownish-gray in color. On opening the heart the right ventricle is normal, as are also the tricuspid and pulmonary valves. The left auricle is thickened but not dilated. *The mitral leaflets are moderately thin and delicate. The tip of the left ventricle shows a tear corresponding in position to that described externally. It is 5 cm. in diameter.* The heart muscle, which is fairly firm and yellowish-brown in color (near the base of the left ventricle measuring 2 cm.), gradually thins out until the deepest portion of the aneurismal sac is reached, where scarcely any muscle-fibers can be found. At the beginning of the sac the heart muscle is pale brown and soft. *The sac is almost entirely filled with soft blood-clot, which shows very beautifully "the lines of Zahn." The clot is attached to the wall of the heart, and measures 11 cm. in thickness; it fills the sac except in the lower portion, in which the tear occurred.* The aortic valves are somewhat retracted, thickened, and calcified, about the sinus of Valsalva. *The descending branch of the left coronary artery* becomes very much narrowed about 3 cm. from its origin, and as it reaches the region of the dilatation, is completely calcified and practically occluded. The circumflex branch and the right coronary artery are patent, but their walls are absolutely stiff and calcareous. The aorta shows moderate arteriosclerosis associated with large areas of ulceration and atheromatous ulcers.

Microscopic Examination: The pericardium contains a good deal of fat, but is normal. The heart muscle is to a large extent degenerated. Certain areas are composed of pinkish granular material, mixed with the remains of muscle-fibers, and some young connective-tissue cells. About the margin of these areas the muscle-fibers are swollen or atrophied, filled with small granules, and destitute of cross-striæ. The nuclei often do not stain. Between the muscle-fibers there is either connective tissue or fat. In some places isolated masses of muscle-fibers are seen, which still retain their structure, but are entirely necrotic. The cells are filled with a golden-brown pigment in the degenerated areas. A few polynuclear leukocytes are found. The thickness of the muscular wall of the heart measures in some sections only 1 mm. Thrombi composed of erythrocytes, leukocytes, and fibrin, all of which take a rather definite eosin stain, are attached to the endocardial surface in some sections. There is no definite organization, but the clot is so clearly welded into the muscular wall that it is impossible to determine where the one ends and the other begins. The intima of some of the small arteries is so much thickened that the lumen in some places is almost occluded.

Diagnosis: Myomalacia; chronic interstitial myositis; thrombosis.
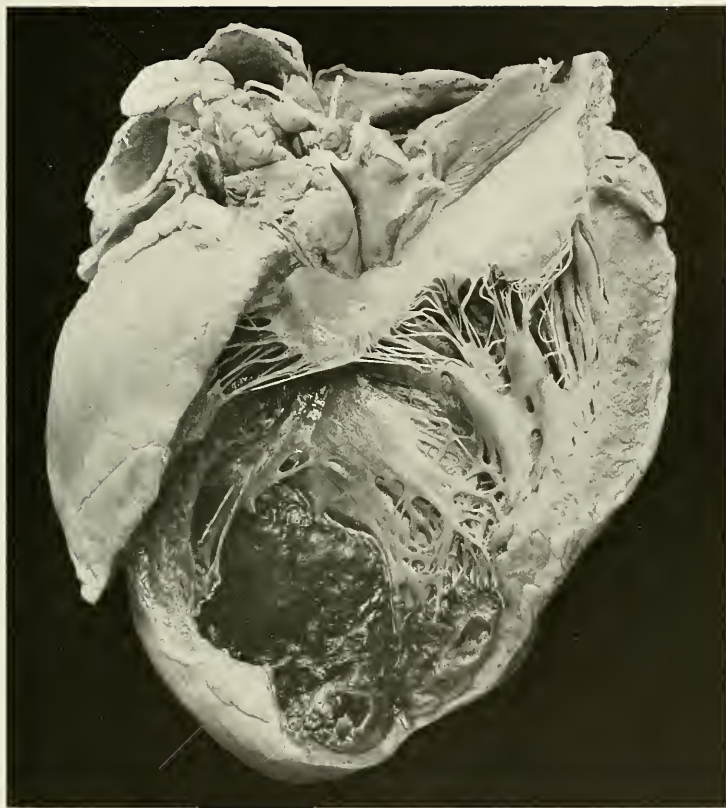
FIG. 59.

The whole subject of chronic myocarditis is still far from satisfactorily understood. There have been great discrepancies of results among different observers, and hence diversities of opinion.

Myocarditis has been attributed to a great number of other factors, such as a strenuous life, physical toil and hardship, chronic infections, and intoxications—metabolic, alcoholic, nicotinic, etc.; but it is very evident that the majority of these factors are of etiologic importance in exact proportion to their tendency to produce vascular damage.

Myocardial changes have also been produced by high temperatures, by the injection of staphylococcus pyogenes aureus, diphtheria bacillus and toxin, strepto-coccus, adrenalin, and ligation of the branches of the coronary arteries.

Of all infectious diseases, *diphtheria* is most commonly accompanied by cardiac dilatation, *scarlatina* being next in frequency. In the majority there is a gradual return to the normal. In *rheumatic fever* 8 out of 18 showed dilata-tion; 7 of these patients also had endocarditis. Three with endocarditis showed no dilatation. None of these cases returned to a normal size (for bodily weight). In *typhoid fever* the return to normal was variable. Five cases of *pneumonia* out of 11 had dilatation which appeared chiefly at the time of the crisis.[1]

The depressing effect of the diphtheria toxin upon the heart has long been recognized, and has been experimentally demonstrated.[2] According to Gossage,[3] the diphtheria toxin depresses contractility, the rheumatic toxin tonicity, hence the greater frequency of death as a result of the former, and dilatation as that of the latter.

In diphtheria the myocardial complications increase with age: 14.3 per cent. in children under two years; 88.5 per cent. between eleven and fifteen years. Cardiac dilatation occurred in 29 out of 40 cases.[4]

Influenza, although occasionally causing endocarditis or myocarditis, gen-erally manifests its cardiac effect by making some already existing lesion worse.[5]

Acute *syphilitic myocarditis* as a secondary manifestation has been described by Jesionek.

Suppurative myocarditis includes two distinct types: (1) Puru-lent infiltration of the heart muscle, generally secondary to such con-ditions as infectious endocarditis, pericarditis, cardiac thrombosis,

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[1] Dietlen (orthodiagraphic studies): Münch. med. Woch., 1908, p. 2077.

[2] Chevalier and Clerc: Soc. Biolog., June 26, 1909.

[3] Gossage: Lancet, Aug. 21, 1909.

[4] Foerster: Deut. Arch. f. klin. Med., 1905, No. 13.

[5] Ruheman: Berlin. klin. Woch., 1910, p. 201.
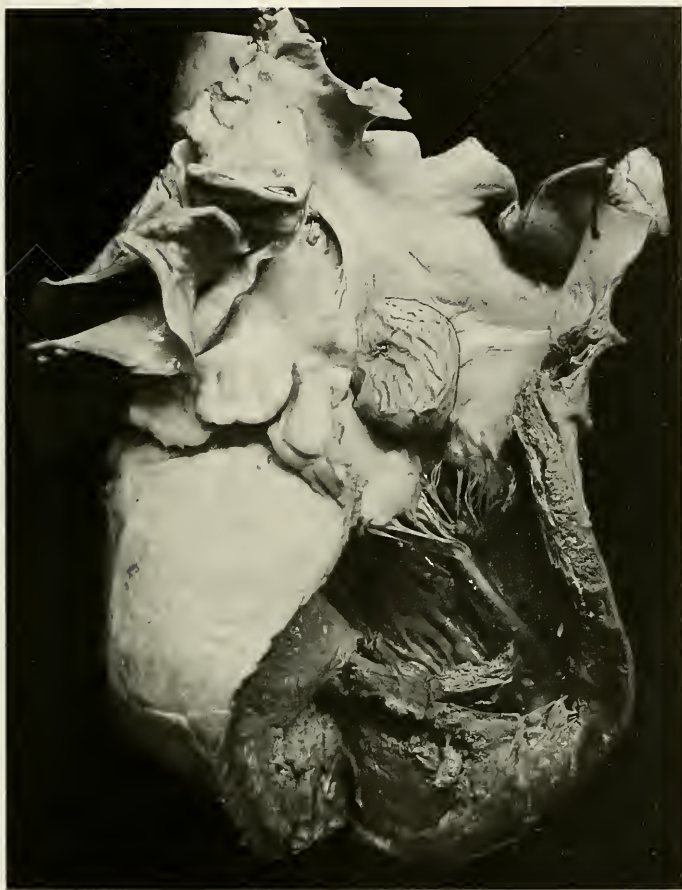
FIG. 60.—CARDIAC THROMBOSIS.

A large rounded thrombus about the size of a large walnut is attached to the auricular surface of the mitral valve. The valvular leaflets themselves are sclerosed and indurated. Another and much larger thrombus is seen occupying the lower and anterior surface of the left ventricle. This has undergone partial organization and is firmly attached to columnæ carneæ and the ventricular endocardium, and very materially reduces the size of the cavity.

septic myocardial infarction, as in pyemia; (2) acute interstitial myocarditis, such as may occur in scarlatina, diphtheria, etc. Beck and Stokes [1] were able to find only one true case of the last-named type recorded, although they collected a number of cases of circumscribed abscess formation. Suppurative myocarditis generally results from septic thrombosis, and the abscesses resulting may vary in size from a pinhead to several centimeters in diameter. Among the 9,940 autopsies studied by the author there were 6 cases of acute suppurative myocarditis.

Clinical Considerations.—While it is doubtless true that the myocardium plays a rôle in all forms of heart disease the importance of which it is difficult to overestimate, yet the term "myocarditis" is often vaguely applied, and such a diagnosis made without ample justification. Thus, in acute diseases death is often attributed to myocarditis when it is really the result of toxic vasomotor paralysis. In these cases blood-pressure, both systolic and diastolic, will be found unduly low, and careful microscopic examination of the heart may show no structural alterations meriting the appellation of myocarditis. Surgical shock, too, is now known to be a vasomotor paralysis, and not to be a result of heart weakness. Sweet has suggested that it may be the result of an acute adrenal insufficiency. A clinical diagnosis of myocarditis is generally based upon evidences of cardiac insufficiency the symptoms of which may be produced by a host of extracardiac and intracardiac causes, associated with which very little myocardial degeneration may be demonstrable at autopsy. On the other hand, cases with well-marked lesions often exhibit disproportionately few symptoms. Cabot found a myocarditis correctly recognized in 22 per cent., overlooked in 26 per cent., and diagnosticated when not present in 52 per cent. of the cases studied by him. We must bear in mind, however, that very small lesions localized to important areas, such as the sinus node, the auriculo-ventricular node or bundle, etc., may

[1] Beck and Stokes: Jour. Am. Med. Assoc., 1910, p. 1065.

FIG. 61.—CARDIAC ANEURISM AND THROMBOSIS.

A large ovate thrombus is seen in the lower part of the left ventricle, the walls of which are visibly thinned and stretched below and behind the thrombus. The endocardium of the ventricle is thickened and opaque, the aorta shows slight arteriosclerotic change, in part involving the mouth of the coronary artery.

Fig. 62.—Mural Thrombosis.

PATHOLOGIC DIAGNOSIS: Mural cardiac thrombosis. Dilatation of the heart, chronic myocarditis, bronchopneumonia.

PATHOLOGIC NOTES: PERICARDIUM: The pericardium contains approximately 20 c.c. of clear yellow straw-colored fluid. The visceral surface is smooth and glistening, with injected vessels. Its visceral surface contains a large, smooth, opaque, white patch measuring 3 x 2 cm. This patch is apparently on the external surface of the middle portion of the right ventricle. There are a few scattered areas similar to the above on the external surface of the right heart. The superior portion of the exterior surface of the right auricle contains a few yellowish-white spots, pinhead size. There is a larger yellowish-white patch, 5 mm. in diameter.

HEART: The heart weighs 530 grams. The heart's flesh is quite firm in consistency and is of a dark red color streaked, in areas, with spots of a lighter red. Both the right and left heart are markedly dilated. The right ventricular walls measures 5 mm. in thickness. The papillary muscles are of a pale reddish-gray color. Clinging to portions of the right ventricular wall, especially toward its tricuspid portion, are masses of a quite firm reddish material spotted with areas of yellow. These masses are quite well attached to the muscular wall, and for the most part lie between the papillary muscles. The right auricle is completely thrombosed by the masses of what appear to be organized blood-clots. The muscle of the right ventricular wall, especially, shows on its under surface very many reddish-yellow patches with small strands of reddish tissue coursing between them, which gives to the surface a mottled appearance. At the base of many of the papillary muscles small whitish patches are seen. The tricuspid valve is well formed and normal in all respects. The pulmonary valve shows no apparent pathologic change, nor do the pulmonary vessels. The endocardium of the right side seems to be intact. *The left ventricular cavity is dilated, measuring at its middle transverse portion 10.5 cm. The muscular wall varies in thickness; thus, at the apex it is but 1 cm. in thickness, while toward the valvular end it measures 1.7 cm. in thickness. Attached to its walls are masses of an organized tissue of a reddish-gray appearance, streaked with coarse strands of a definite yellow-white. These masses cling to nearly all portions of the left ventricular wall, measuring from 0.5 to 2.5 cm. in diameter, and do not appear to cling to the endocardium at any point.* The condition of the heart muscle, at its junction with these clots, has a most peculiar appearance. Where the clots meet the true muscular wall there appears to be a definite yellow line, in many portions showing distinct demarkation. These clots interweave among the papillary muscles, are quite firm in consistency, and show definite evidences of well organized tissue. The mitral valve is normal. The left auricle contains the same kind of thrombi as does the ventricle. The aortic ring measures 6 cm. The aortic valves are well formed and are normal in all respects. There is no evidence of any sclerosis of the larger vessels. The coronary arteries are patent; their walls are smooth and no sclerosis can be found. (Pennsylvania Hospital, No. 1060.)
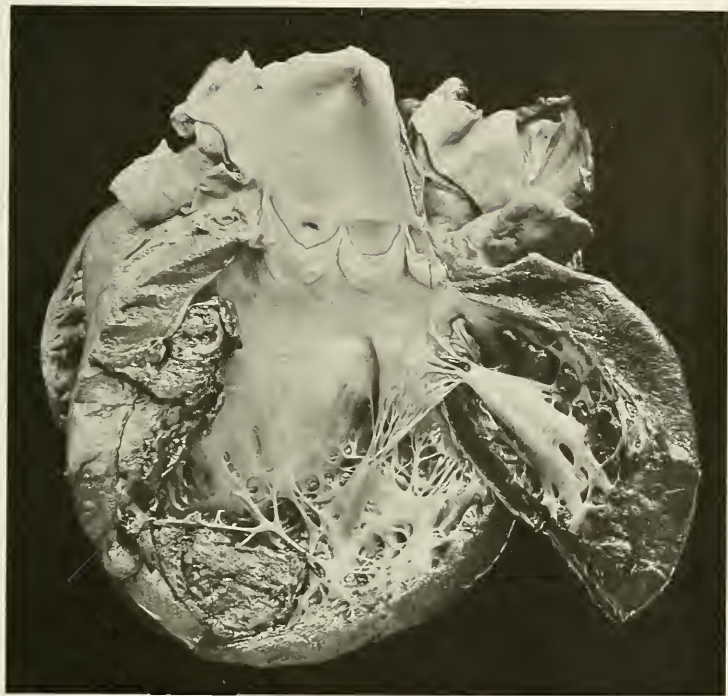
Fig. 62

apparently be responsible for serious damage when the rest of the myocardium is comparatively healthy; and that disease of these structures is generally undemonstrable during a routine autopsy. It is to be hoped that the careful routine examination of these areas in large series of cases will throw much light upon the at present unsatisfactory status of "myocarditis."

CORONARY ARTERIOSCLEROSIS

The nutritional supply, and hence the functional integrity, of the whole heart depends very largely upon the condition of the coronary arteries. As long as the blood-supply is adequate the heart can cope with the most surprising mechanical odds. It is not surprising, therefore, that sclerosis of the coronary arteries should be the most serious form of heart disease.

As a general rule, gradual narrowing of a coronary artery is followed by fibroid or fatty change in the myocardium, whereas sudden occlusion, as may occur from embolism or thrombosis, produces an area of softening somewhat smaller than the anatomic area supplied by the vessel. (See Section IX.)

Although the earlier teaching, that the coronaries are end-arteries which practically do not anastomose, has been in a strict sense disproved by the researches of Hirsch and Spalteholtz,[1] Jannin and Merkel;[2] and although cases have been reported in which occlusion of large arteries, such as the right coronary, may occur without subsequent myocardial change (Marchiafava,[3] Chiari); and although the last-named artery has been ligated in man without subsequent muscular degeneration (Pagenstecher[4]), yet these cases are exceptional, and must be explained as due to anomalous blood-supply or incomplete occlusion. Cases of the opposite sort have also been noted, as, for instance, that of F. T. Stewart, in which a human heart sutured some years before for trauma,

[1] Hirsch and Spalteholtz: Deut. med. Woch., 1907, p. 790.
[2] Jannin and Merkel: Die Koronararterien des Menschlichen Herzen, etc., Jena, 1907.
[3] Marchiafava: Revist. critica di clin. med., 1904.
[4] Pagenstecher: Deut. med. Woch., 1901, p. 56.
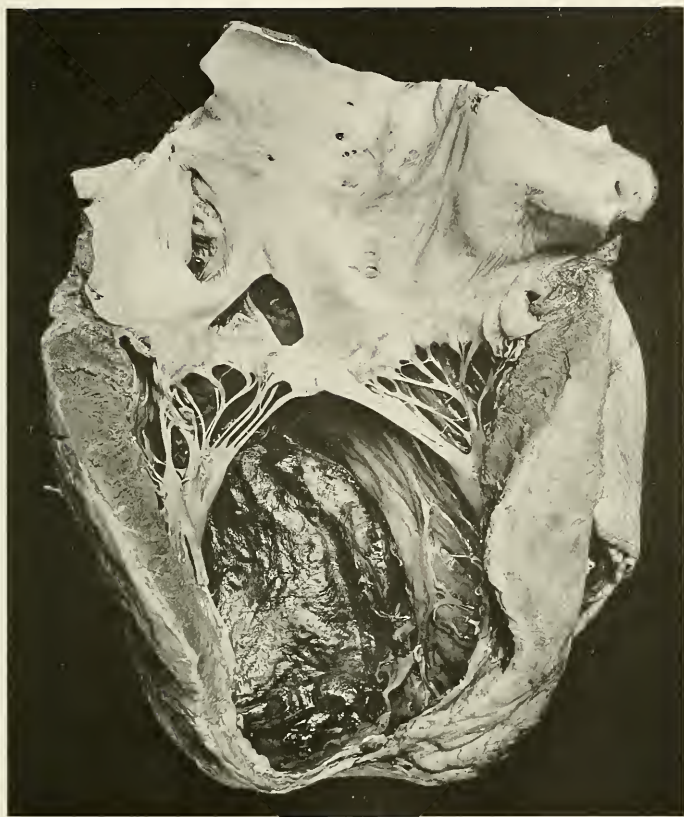
FIG. 63.—CARDIAC ANEURISM AND THROMBOSIS.

The musculature of the left ventricle near the apex is thinned and stretched; its chamber is nearly filled with a large, dark, glistening, adherent thrombus, which shows the "lines of Zahn." The mitral valve is moderately sclerosed. (Photograph by Dr. Alfred R. Allen.)

disclosed a fibroid myocarditis originating at the site of the original ligature.

When the coronary arteries are ligated in animals, death may occur suddenly,[1] preceded by fibrillation, or it may occur in the course of minutes,[2] hours,[3] or weeks.[4]

But we must bear in mind that in animals we are dealing with healthy hearts which we know are able to sustain a great deal of traumatic insult. Embolic or thrombotic manifestations, on the other hand, rarely occur in conjunction with a previously healthy myocardium.

Based on original investigation and a review of the literature, Amenomiya[5] draws the following conclusions regarding the coronary arteries and the papillary muscles. The *right coronary artery* supplies the greater part of the right heart, the posterior part of the ventricular septum, and part of the posterior part of the left heart. The *left coronary artery* supplies the most of the left heart, the anterior part of the ventricular septum, and part of the anterior wall of the right heart. In the papillary muscles the terminal bifurcations occur as straight, longitudinal, and radiating branches. The anterior papillary muscle of the left ventricle is supplied solely by the ramus descendens of the left, and the posterior by both branches of both coronary arteries. The large anterior papillary muscle of the right ventricle derives its nourishment from both arteries, the branch from the left artery being given off relatively high up from the ramus descendens. The vessels supplying the papillary muscles double upon themselves upon entering, thus describing a considerable curve. The foregoing anatomic facts, which are unfavorable to perfect circulatory efficiency, *explain why the papillary muscles, especially the anterior ones, are so frequently the seat of infarction and fibrosis.* It has been shown that during acute infections the coronary arteries show pathologic alterations before the other vessels of the body, and that the structural damage thus produced may lead to arteriosclerosis.[6]

Pathogenesis.—The effects of arteriosclerosis of the coronary arteries may be due either to disease of the artery itself throughout its course, or to constriction of its orifice resulting from disease of the aorta. The types of coronary arteriosclerosis are similar to those affecting other arteries—localized or general thickening,

[1] Magrath and Kennedy: Jour. Exper. Med., 1897, p. 13. Porter: Jour. Physiol., 1893, p. 121.

[2] Cohnheim and v. Schulthess Rechberg: Arch. f. path. Anat., 1881, p. 503.

[3] Panum: Ibid., 1863, pp. 308, 433.

[4] Baumgarten: Am. Jour. Physiol., 1899, p. 243.

[5] Amenomiya: Virchow's Arch., 1910, cic, 187.

[6] Wiesel: Wien. klin. Woch., 1906, No. 26. Wiesner: Centralb. f. med. Wissensch., 1907, No. 3.
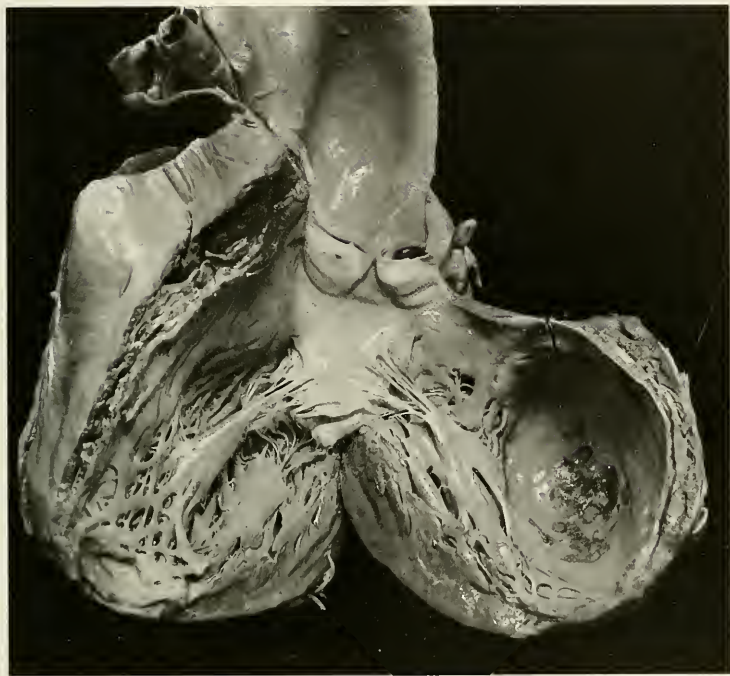
FIG. 64.—ANEURISM OF THE LEFT VENTRICLE.

The left ventricular wall, which is elsewhere hypertrophied, is markedly attenuated on its left side at and above the apex. In this region a marked bulging, about the size and shape of a large duck egg, is seen. The endocardium in this region is covered with calcareous plaques. The aortic and mitral valves show moderate sclerosis. (Specimen from the Philadelphia Hospital. Vol. xv, p. 39. Physician: Dr. F. P. Henry.)

roughening, hardening, or actual calcification being met with. On account of the smaller caliber of some of the branches, occlusion may readily occur and thrombosis result, especially if the blood-pressure is lowered or the orifices are constricted. Such constriction is of frequent occurrence. Up to thirty years of age the elastic tissue in the aorta increases.[1] Both Adami and Aschoff regard this as a work hypertrophy. For the following fifteen years the amount of this connective tissue remains stationary. After fifty years there is a slow, progressive wasting of the elastica, and a stretching and thinning of the media occurs. "The dominant primary event in the arteriosclerotic process—syphilitic, senile, functional—is a localized, or it may be diffuse, weakening of the arterial wall, and especially of the media. This induces increased strain upon the remaining coats; and if this be not excessive, that strain leads more especially to connective-tissue overgrowth and the development of the characteristic lesions of arteriosclerosis" (Adami). Syphilitic disease of the aorta is a relatively frequent manifestation of this infection. It is apt to occur early in life, to be of a serious and progressive nature, and, as already pointed out, to affect just that portion of the aorta from which the coronary arteries arise. In addition to lues, certain acute infections, such as typhoid and rheumatic fevers, and certain chronic infections, such as rheumatoid arthritis, often seem to produce arteriosclerosis.

Three more or less distinct types of arteriosclerosis of the larger vessels occur in man: (1) The ordinary nodular form; (2) dilatation of the vessels with increased tortuosity, the peripheral arteries being of the "pipe-stem" variety, and (3) the syphilitic type, affecting chiefly the ascending aorta, in which the nodules eventually cause depressions in the intima. This is primarily a mes-aortitis, with wasting of the media, and with thickening of the other coats.

In 1,000 consecutive autopsies Brooks[2] found coronary sclerosis of sufficient degree to "seriously affect the nutrition of the heart " in 270 cases. The earliest instance occurred in a boy of fifteen years, the average age being forty-five years. The following associated conditions were found: Chronic alcoholism, 107;

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[1] Foster: Jour. Med. Research, Sept., 1909.
[2] Brooks: New York Med. Jour., 1906, p. 825.
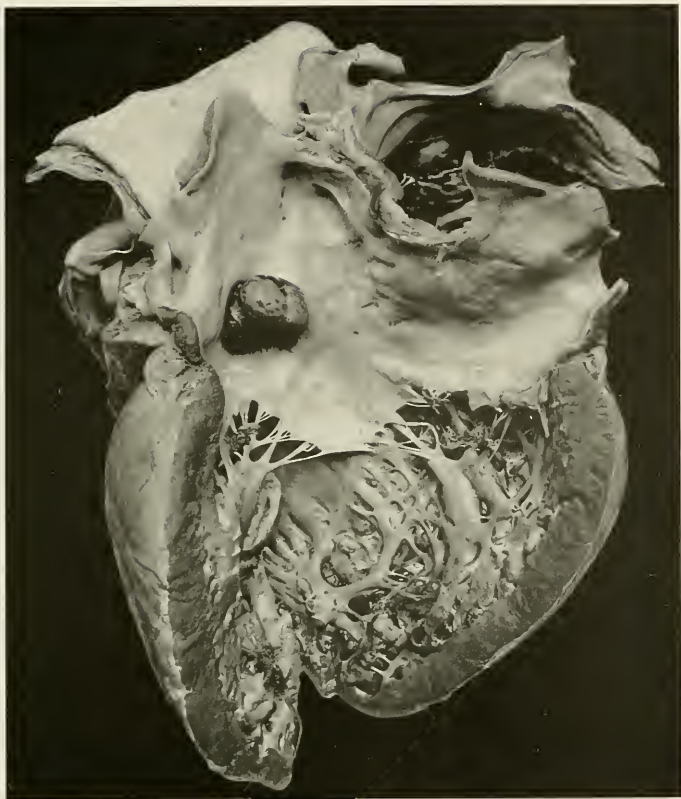
Fig. 65.—Ball Thrombus in the Left Auricle.

A large, dark, ball-shaped thrombus lies free in the left auricular cavity. Numerous smaller mural thrombi are seen enmeshed in the columnæ carneæ and chordæ tendineæ. The left ventricular wall, which is elsewhere hypertrophied, is noticeably thinned near the apex. (Photograph by Dr. Alfred R. Allen.)

nephritis, 35; syphilis, 30; tuberculosis, 20; carcinoma, 1; diabetes, 6; plumb-ism, 2. All but 15 showed macroscopic myocardial lesions. In 215 cases these changes were sufficient to be considered as contributory to the cause of death. The following lesions were observed: Brown atrophy, 64; fibrosis, 24; hyper-trophy, 35; acute dilatation, 20; aneurism, 2; cardiac rupture, 2. At the Philadelphia General Hospital, which is very rich in such material, among 8,640 autopsies the following myocardial lesions were encountered: Acute suppurative myocarditis, 5; myocardial thrombosis, 28; sarcoma, 4; carcinoma, 4. At the Pennsylvania Hospital among 1,300 autopsies there was 1 case of coronary aneurism and 10 cases of coronary obliteration. (See page 48.)

Arteriosclerosis of the coronary artery is the commonest pathologic finding in cases of angina pectoris.

Among 83 cases of angina pectoris Bouchard found only 12 with a history of syphilis. Among 261 syphilitics, 4.5 per cent. suffered from angina pectoris; among 3,739 non-syphilitics, only 2 per cent. did. Of the above mentioned 261, 14 per cent. presented aortic lesions.[1]

The left coronary artery generally shows the most marked sclerotic changes. These appear as localized or diffuse thickening, especially at the points of bi-furcation or branching. Partial occlusion generally results in myomalacia cordis, which, if several contiguous areas are involved, results in aneurismal dilatation.

The localization and extent of arteriosclerosis is to a certain extent depen-dent upon functional activity. Boveri's[2] experiments on animals tend to con-firm the clinical view that hard muscular work leads to arteriosclerosis. In laborers the location of the most pronounced vascular lesions corresponds to the part of the body which performs most of the work—the lower extremities in knife-grinders, the upper extremities in wood- and stone-cutters. It is not im-probable that fatigue toxins have some effect. It has sometimes been possible to determine post mortem by the amount of arteriosclerosis which organ of the body functionated most actively during life.[3] An indication that such arterio-sclerosis may be the result of increased blood-pressure may be found in the fact that rabbits suspended by the hind legs for three minutes daily over a period of one hundred and twenty days showed well-marked arterial lesions in the upper part of the body.[4] A normal pressure with weakened media, or an increased pressure with a normal media, may cause a giving way of the arterial coat with secondary intimal changes. To a certain extent the toxins of disease exert a specific selective action. Klotz and Saltykow[5] have shown that diphtheria affects the media, while the typhoid fever exerts its noxious influence on the intima.

That syphilis is one of the commonest, if not the commonest, causes of sclerosis of the aorta cannot be doubted. In a study of 54 cases by Bittdorf[6]

[1] Arch. du Mal du Cœur, 1909, p. 98.
[2] Boveri: Riforma Medica, 1909, No. 30, 31.
[3] Askana: Therapeut. Monatshefte, Sept., 1907.
[4] Klotz: Quoted Adami, Am. Jour. Med. Sci., Oct., 1909.
[5] Saltykow: Ziegler's Beiträge, 1908, xlii, 187.
[6] Bittdorf: Deut. Arch. f. klin. Med., lxxxi, 1904, No. 122.

the average age at which this lesion occurred was 55.6; in syphilitics the average age was ten years younger. Huchard[1] in a study of 1,835 cases of arterio-sclerosis seen in private practice found a history of gout in 323, of rheumatism in 332, of syphilis in 209, of the abuse of tobacco in 181, of infectious disease in 67, of alcohol in 27.

Although the arteriosclerosis produced by means of adrenalin, barium chlorid, nicotin, etc., differs from that which occurs spontaneously in man, inasmuch as in the former the changes are limited almost entirely to the media, yet both of these types have as a common basis a giving way of the media. Adami suggests that the intimal changes are lacking in the experimental variety on account of their acuteness, and considers that the arterial thinning of the Mönkeberg type, and the intimal thickening of senile arteriosclerosis, are diverse manifestations of a common process.

[1] Huchard: Bull. de l'acad. d. Méd., July 15, 1908.

XI. CARDIAC ANEURISM

Aneurism of the myocardium consists of a localized bulging of the heart, and is brought about through stretching of the softened muscle or the fibrous tissue which displaces a diseased myocardium. At times the septum is involved. Rarely the aneurism is an extension of the aneurismal dilatation of one of the valves, *e. g.,* the mitral, with secondary involvement of the wall of the heart.

The fibroid degeneration which precedes the aneurism may result from coronary sclerosis, either the mouths or the terminal branches of these vessels being diseased. Chronic endocarditis and the traction of pericardial adhesions are also causative factors in some instances. Cardiac aneurism is distinctly rare, and except in those cases where rupture produces hemopericardium and sudden death, it is often discovered unexpectedly at autopsy. (See "Coronary Sclerosis," p. 180.)

The condition is generally single, although multiple aneurisms have been noted. The myocardium, which may be greatly thinned and stretched, is replaced to a greater or less extent by fibrous tissue. At times the opening into the aneurism is constricted and forms a dilated sac beyond, but this is not generally

FIG. 66.—RUPTURE OF THE AORTA.

M. S., male, white, aged fifty-one years. (Philadelphia Hospital. Autopsy vol. xix, p. 281. Physician: Dr. Mills. Pathologist: Dr. J. D. Wilson.)

CLINICAL NOTES: Arrhythmia; pulse 90. *Sudden death,* with marked cyanosis and rigidity of the body.

PATHOLOGIC DIAGNOSIS: *Rupture of the aorta;* chronic interstitial nephritis, with acute exacerbation; nutmeg liver; general arteriosclerosis.

PERICARDIUM: Extends from the right border of the sternum to the left axillary line. On incision, blood spurts freely. The cavity contains 1,000 c.c. of fluid blood, and an equal amount of blood-clot.

HEART: Weighs 750 gm., has a normal color. *Myocardium is thickened and firm. Endocardium normal except for small patch of atheroma on the aortic valve. In the aorta, 2 c.c. above the valve margin, there are two openings, one a vertical slit 3 cm. long, which forms an opening from the aorta to the pericardial cavity. The other, 6 cm. long, is situated directly opposite, but extends only to the connective tissue surrounding the vessel.* This tissue surrounding the lateral slit is markedly reddened and swollen.
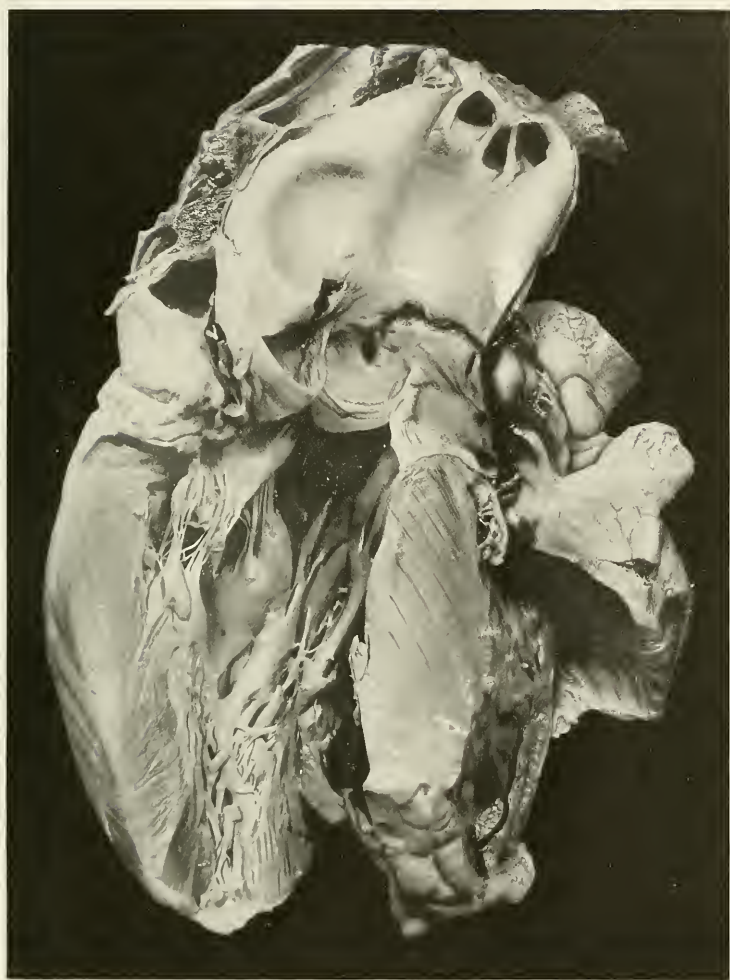
FIG. 66.

the case. Aneurisms are generally found on the anterior surface of the left ventricle above the apex. Such dilatation has clinically simulated a pericardial effusion to such an extent that aspiration was performed and blood withdrawn from the left ventricle.[1] Among the 1,300 Pennsylvania Hospital autopsies there were 5 cases of cardiac aneurism; at the Philadelphia Hospital, 3 among 8,640. Legg found 3 in 1,899 autopsies.

To parietal endocarditis has also been ascribed an etiologic

[1] W. Pepper: University of Penna. Med. Bull., vol. i.

FIG. 67.—GUMMAS OF THE MYOCARDIUM. (Right heart.) (See also Fig. 68.)

Male, aged thirty-eight years. (Pennsylvania Hospital. Specimen 239. Physician: Dr. A. V. Meigs.)

CLINICAL NOTES: Patient's health had been poor for the last few years; he had complained of frequent micturition and asthma. He had at one time had swelling of the feet. Before the present attack he had no distinct convulsions, but had had frequently what he called "*spells.*" He denied ever having had syphilis. At the time of his admission to the hospital he was in a state of partial collapse, with cyanosis, cold extremities, vomiting, and retching. The heart action was "excessively slow" and irregular, "there being when the patient first came into the ward two or three respirations taken for each beat of the heart." There was a loud blowing murmur at the apex. On the day following the patient frequently complained of feeling faint, and during these attacks objects swam before his eyes. Cyanosis and cold extremities were constant. The murmur still persisted, but was heard louder at the base of the heart. Pulse 34, respirations 18, temperature 98° F. Five days later the patient uttered a shriek and *died suddenly.*

PATHOLOGIC REPORT: "The specimen shows a heart with *a firm, nodular mass situated in the septum and reaching from the tricuspid valve into the right auricle, and also making a projection into the left ventricle just below the aortic orifice; its size is about that of a walnut.* In the right auricle it juts forward directly over the tricuspid orifice, and in the left ventricle it involves nearly the whole of the ventricular surface of the aortic cusp. Its tissue is firm, somewhat elastic, and on section shows a pretty uniform consistence and a gray color. Numerous firm clots are entangled in the columnæ carneæ of the right ventricle, which are continuous through the tricuspid orifice and pulmonary artery. The organ weighs 17½ ounces. A microscopic examination showed the characteristic appearance of a syphilitic gumma." (Meigs.[1]) "*Further examination of the preserved specimen shows that this nodular mass obliterates the undefended space of the interventricular septum, and entirely fills that part of the septum through which the auriculo-ventricular bundle runs.* It is the posterior leaflet of the aortic valve into which the gumma has grown. To the right of this leaflet there is a small second nodule 10 x 7 mm. The root of the aorta is corrugated and appears to be the seat of a syphilitic aortitis." (Robinson.)

There is every reason to believe (although this case was first reported long before the existence of the auriculo-ventricular bundle was known, or its function understood) that we had here to deal with a case of auriculo-ventricular heart block due to a gumma of the myocardium involving the interventricular septum.

[1] This case was reported by Dr. A. V. Meigs in the Transactions of the College of Physicians of Philadelphia, 1881, third series, vol. v; further studied and reported by Dr. G. C. Robinson in the Bulletin of the Ayer Clinical Laboratory, 1907, No. iv.
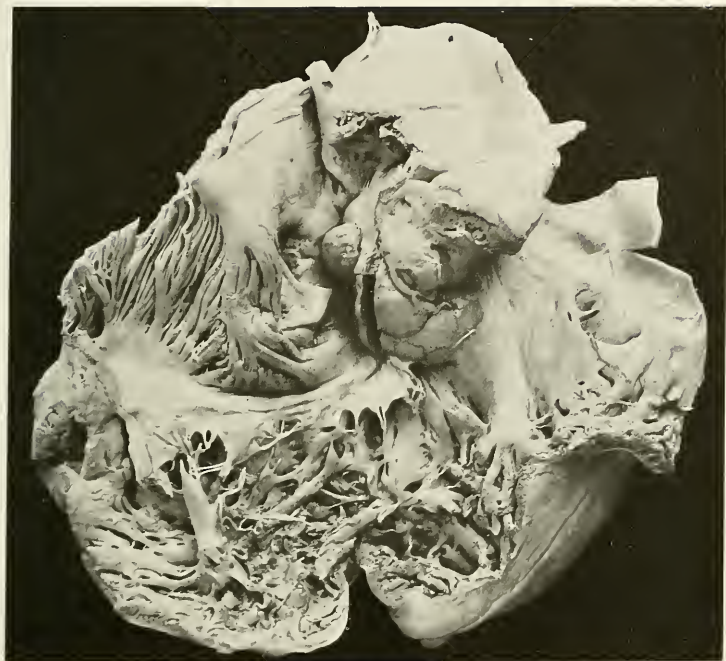
FIG. 67.

rôle.[1] Such a case has recently been reported by Bret and Roubier.[2] Cardiac aneurism may also result from traumatic scar formation, suppurative foci, or gummatous myocarditis.

According to M'Elroy,[3] there are now on record in medical literature some 300 cases of myocardial aneurism. Warthin states that the condition may be congenital. Among 208 cases collected by Hare, 74 per cent. occurred in men. Only about 7 per cent. of the chronic cases terminate in rupture.

Actual calcification of the myocardium is distinctly rare, and its pathology not thoroughly understood. Apparently the calcification occurs as a sequel to muscular degeneration. Hart,[4] who has collected 13 cases, has suggested that hyaline, glycogenic, and amyloid changes may be the real substratum of the condition. Topham has reported actual bone formation in the heart of a man dying at the age of seventy-one.[5]

CARDIAC THROMBOSIS

"The term cardiac thrombosis must be reserved for a solid or partly solid structure, primarily formed from the blood-elements, which develops in one or more of the heart chambers during life. Such a mass may be attached to the cardiac wall by a more or less altered base, or may exist as a free foreign body within a heart cavity. When cardiac thrombi are measured by this standard they are uncommon post-mortem findings."[6] For the production of cardiac thrombosis three factors are necessary: first, local endocardial injury—mechanical, bacterial, or toxic; second, an increase of hemagglutinins in the blood; and, third, slowing of the blood-stream. Thrombi are met with in valvular heart disease, in cachectic states, and in blood dyscrasias. In the first-named class they may begin as vegetations. Infectious diseases

[1] Strauch: Zeit. f. klin. Med., 1900, p. 231.
[2] Bret and Roubier: Arch. d. Mal. du Cœur., 1910, p. 445.
[3] M'Elroy: Jour. Am. Med. Assoc., Aug. 1, 1908.
[4] Hart: Zeit. f. Patholog., 1909, iii, 706.
[5] Topham: Brit. Med. Jour., Oct. 13, 1906.
[6] Smithies: Jour. Am. Med. Assoc., 1909, p. 1347.
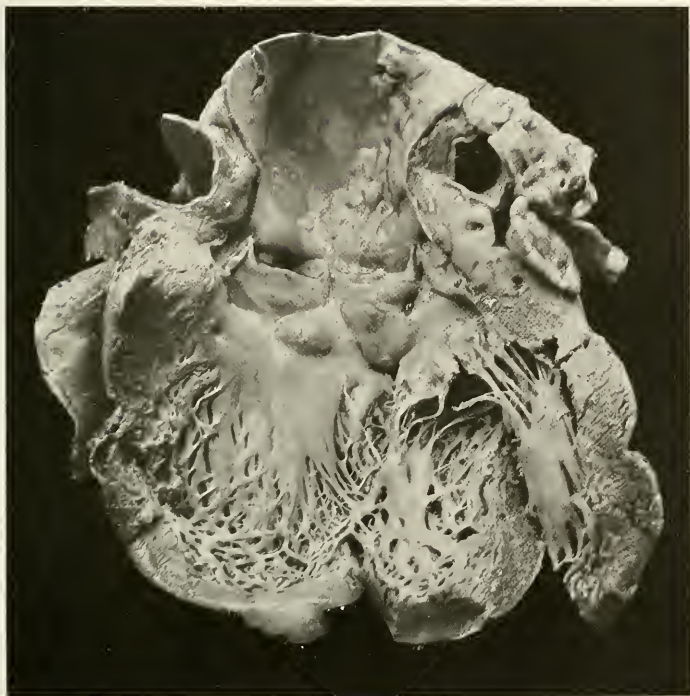
FIG. 68.—GUMMAS OF THE MYOCARDIUM. (Left heart.) (See legend under Fig. 67.)

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except influenza and tuberculosis are rarely complicated by throm-
bosis. The most common site is in the left auricle, the right auricle
and the left ventricle coming next in frequency, while "primary
thrombosis of the right ventricle appears to be unknown."

Thrombosis is probably more common in mitral stenosis than
in any one other condition. It is also met with in cardiac dilata-
tion, especially when sclerotic endocardial or myocardial changes
are present. Hence it is more common in the later years of life,
although it has been described in childhood. The shape of the
thrombi varies considerably, but generally they can be classified
either as pedunculated or of the ball variety, the former being
the more common. The effect of cardiac thrombosis upon the
circulation is generally marked. Such a condition interferes
considerably with cardiac contraction and with the transference
of blood from one chamber to another, so that from a diagnostic
standpoint the severity of the symptoms is out of all proportion
to the apparent degree of the cardiac lesion. At the Pennsylvania
Hospital there were 6 cases in 1,300 autopsies; at the Philadelphia
Hospital, 28 among 8,640.

Cardiac rupture may occur as the result of fatty degeneration,
aneurismal dilatation, suppurative myocarditis, acute necrosis,
gummatous disease, and brown atrophy. This condition was
first described by Harvey, and later by Morgagni. Among
Quain's 100 collected cases 77 were due to fatty degeneration.
Most of the patients were beyond sixty years of age, and sudden
death occurred in 71 per cent. The site of rupture was as follows:
Left ventricle, 55; right ventricle, 7; right auricle, 3; left auricle, 2.
Rupture may be complete or incomplete. It is slightly more
frequent in males. In 18 of Letulle's 110 cases, multiple rupture
was found. Occasionally rupture occurs in apparently healthy
young people as the result of coronary thrombosis.[1] Quain's
cases included two between the ages of ten and twenty. *Rupture*

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[1] Klingmann: New York Med. Jour., 1908, p. 199.
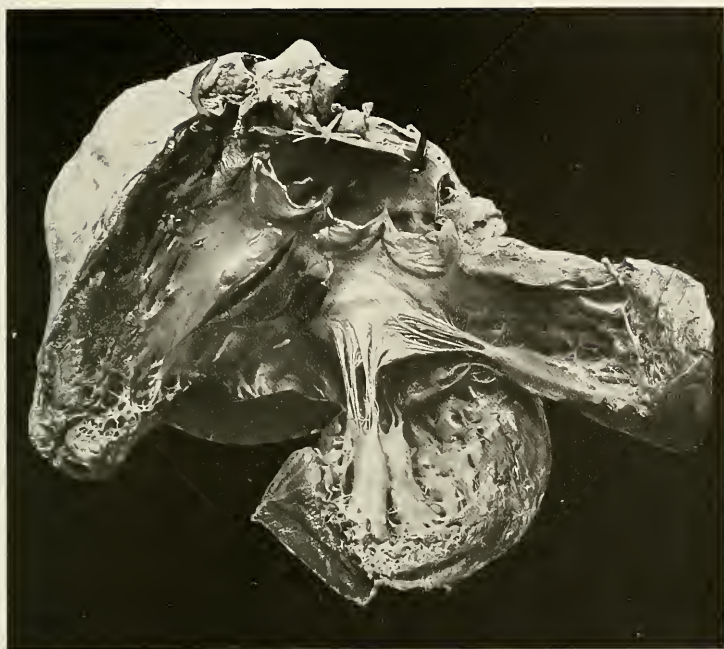
FIG. 69.—GUMMA OF THE MYOCARDIUM.

A large, firm, nodular mass is seen in the septum below the aortic valves which bulges forward into the ventricle. Another mass is seen in the wall of the ventricle. These masses were firm, slightly elastic, grayish in color, and upon microscopic examination showed typical gummatous structure.

The heart is that of a patient aged thirty-one years, who had contracted syphilis eight years before. Three years previous to admission he had been incapacitated for three days by an "inflammation of the heart." Six weeks before admission he had had fugacious pains and loss of power in the right hand. A few days afterward he had a syncopal attack while at work, following which he developed headache, weakness, numbness of the legs, and diplopia. On admission to the hospital he was found to have a right-sided hemiplegia. On auscultation a mitral systolic murmur was noted. During his three months' stay in the hospital he had hemoptysis and cardiac pain. (Pennsylvania Hospital, No. 301. Dr. J. M. DaCosta.)

of a papillary muscle is extremely rare. Dennig[1] has reported a case, and alludes to the scanty literature on the subject. It may follow great increase of blood-pressure, especially with a diseased myocardium, or it may result from crushing trauma of the thorax or from ulcerative processes. Spontaneous cardiac rupture is to be differentiated from the traumatic variety —the question is often of medico-legal importance—as follows: The former occurs chiefly in advanced years; the parietal pericardium shows no lesion, the heart muscle near the site of the tear generally does. The tear is usually near the apex in the left ventricle, and assumes a zigzag outline. Although it has been stated that a perfectly normal heart may rupture under great strain, this is very questionable. Such cases probably always have a preceding pathologic basis which predisposed to the rupture (Thorel[2]). Geill,[3] in an analysis of 90 cases of traumatic cardiac rupture produced by blows delivered with dull instruments, etc., found the right ventricle frequently, and the left rarely, injured. There is much discrepancy of opinion as to whether the tearing, crushing, or bursting element is the most important in the mechanism of traumatic rupture. The mode of death in such cases depends upon whether the exudation of blood into the pericardial sac is sudden or gradual. In the former we may have an actual mechanical compression—"tamponade"; in the latter a gradual interference with diastole through the secondary effect of the depressor nerve on the vasomotor center (Placzek[4]). In the former the pericardium will be tensely distended and the heart collapsed; in the latter both of these conditions will be less marked.

The distribution of cardiac rupture among 8,640 autopsies at the Philadelphia Hospital was as follows: One of the left ventricle, two of the left auricle, one of a papillary muscle.

[1] Dennig: Deut. Arch. f. klin. Med., 1909, p. 163.
[2] Thorel: Lubarsch and Ostertag's Ergebnisse, 1907, ii, 425.
[3] Geill: Viertel Jahrschr. f. Gericht. Med., 1895, xvii.
[4] Placzek: Ibid., 1902.

FIG. 70.—GUMMA OF THE LEFT VENTRICLE. (Specimen from the Pennsylvania Hospital.)

Among 132 cases Odriozola[1] found the site of the rupture to be as follows: Left ventricle, 96; right ventricle, 22; left auricle, 2; auriculo-ventricular groove, 2.

The size of the tear in the spontaneous cases varies, but is generally from one-half to one inch in length. Not infrequently the tear is larger on the outside than on the inside. The rupture is often that of an "X" or a "Y." Ruptures generally occur during muscular strain, but may do so during sleep. As a historic example it may be recalled that George the Second died of a ruptured right ventricle.

Spontaneous rupture of the aorta without preceding aneurismal dilatation is occasionally met with. It generally occurs in the aged, and is associated with atheromatous or sclerotic vascular disease, but at least two cases have been reported in children under fourteen years of age in whom the aorta showed only very slight evidences of disease, on account of which a congenital weakness of this structure was assumed.[2]

TUMORS OF THE HEART

Primary neoplasms of the heart are extremely rare. There were no such cases among the 9,940 autopsies studied by the author, nor among 3,000 reviewed by Thorel.[3] Of 110 cases of heart tumors found in the Index Catalogue of the Surgeon-General's Library the majority were secondary. The mesoblastic origin of the heart accounts for preponderance of sarcomata (Hektoen[4]). A recent compilation of cases by Link[5] shows the following data: total number of primary heart tumors, 91. Among 61 of these the character of the growths was as follows: Sarcoma, 13; myxoma, 18; carcinoma, 7; lipoma, 8; myoma, 5; rhabdomyoma, 1; teratoma, 1; papilloma, 1. The growths were distributed:

[1] Odriozola: Etude sur le cœur senile, Paris, 1888.

[2] The literature on this subject can be found: Bergé: Gaz. d. Hôpit., 1906, No. 38. Thorel: Lubarsch and Ostertag's Ergebnisse d. allg. Path., 1907, ii, 577.

[3] Thorel: Lubarsch and Ostertag's Ergebnisse d. allg. Path., 1903, pt. 1; 1907, pt. 2.

[4] Hektoen: Med. News, 1893, p. 571.

[5] Link: Zeit. f. klin. Med., 1909, p. 272.

Left auricle, 24; valves, 16; right ventricle, 14; right auricle, 10; left ventricle, 8; interauricular septum, 2; both auricles, 3; both ventricles, 2; right auricle and ventricle, 2; left auricle and ventricle, 2; at the junction of the auricular and ventricular septa, 2. In the foregoing study gummas, cysticerci, and secondary tumors were excluded. The age of the patients in Schoeppler's series ranged from three days to eighty-three years.[1] It has quite frequently happened that the heart has manifested very few symptoms of insufficiency even with extensive myocardial involvement.[2]

[1] Schoeppler: Münch. med. Woch., 1906, liii, No. 45.

[2] Another case of sarcoma has recently been reported by Ehrenberg, Upsala, Lakarefoerings Forhandlingar, 1910, xv.

XII. CARDIAC SYPHILIS

Occurrence.—Syphilis of the heart was first described by Ricord in 1845. Virchow distinguished two distinct types: (*a*) gumma formation; (*b*) diffuse interstitial change. In 1904 Stockman collected 80 cases of the former type. Mraček has published the pathologic findings of 102 cases, he having found 4 cases of cardiac syphilis among 150 autopsies. Loomis found 4 cases in 1,500 autopsies, and describes amyloid change resulting from this infection. Among 61 of Mraček's cases gummas occurred in about 50 per cent. Any part of the myocardium, endocardium, or pericardium may be involved. A considerable number of cases of the Adams-Stokes syndrome showing gummatous lesion in the auriculo-ventricular bundle are now on record. The Pennsylvania Hospital statistics showed 2 cases in 1,300 autopsies; the Philadelphia Hospital records, 1 in 8,640.

Pathologic Anatomy.—*Gummatous cardiac disease* consists of circumscribed tumor-like masses which on section appear dry and yellowish or grayish in color. The lesions are chiefly encountered in the ventricles, though the auricles, and especially the interventricular septum, are often diseased. The involvement is generally multiple, the size ranging from 0.5 cm. upward. If breaking down occurs, cardiac sclerosis or aneurism may result. The gummatous cases are usually accompanied by more or less diffuse fibrous change. The gummas show the characteristic histologic structure. They are generally sharply defined and encapsulated. In the fibrous type involvement of the endocardium and the pericardium is more frequent than in the gummatous variety. As might be expected, vascular changes in the coronary vessels are common findings. Syphilitic endocarditis and pericarditis are generally secondary to myocardial disease. The fibrous type of cardiac syphilis is essentially a microscopic
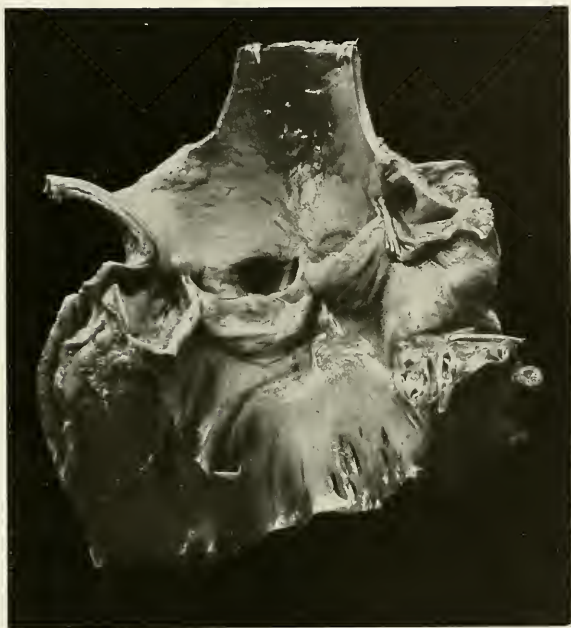
FIG. 71.—SYPHILITIC AORTITIS.

Syphilitic mesaortitis occurs characteristically about one and one half inches above the aortic valves, often spreading downward and involving the mouths of the coronary arteries and the leaflets secondarily. The surface of the aorta appears depressed—not elevated as in the ordinary arteriosclerotic lesions. It is a prolific source of aortic aneurism, and aortic rupture. (See "Cardiac Syphilis," p. 200, and "Diseases of the Aortic Orifice," p. 50. Compare Figs. 41, 66, 72.)

lesion. It is of considerable rarity.[1] Warthin has described diffuse myocardial fibrosis due to congenital syphilis,[2] and productive mesaortitis as a hereditary lesion has been reported by Bruhns,[3] Wiesner,[4] and Klotz.[5]

That mesaortitis is frequently the result of syphilis has been shown by the demonstration of the Spirochœta pallida in these lesions.[6] The lesion is generally confined to the arch of the aorta, or, as in the case depicted in Fig. 71, extends only about 5 cm. above the aortic valves. It is definitely localized and often abruptly circumscribed. Longcope found 21 cases of chronic aortic endocarditis without involvement of the other valves among 930 autopsies at the Pennsylvania Hospital. "In the least extensive areas there were patches of thickening 2 or 3 cm. in diameter. The central portion was elevated, gray, and somewhat succulent in appearance, while the margins were yellowish and crinkled. The sclerosis, when more extensive, was characterized by an irregular corrugated or crinkled thickening of the wall, showing small pits and sometimes minute aneurismal sacculations. Often the bases of these small aneurisms were so thin that they transmitted light. There was no calcification except in one instance, but rather a rubbery pliable thickening. In 4 cases the arch of the aorta was the seat of large aneurismal formations. The valves showed the same rubbery thickening when extensively involved, and occasionally there were crescentic lines of whitish-yellow thickening on the endocardium of the ventricle beneath the valves." The diagnoses in these cases were corroborated by microscopic examinations, and extension downward into the aortic

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[1] For further information see Mraček, Arch. f. Dermat. u. Syphilis, xxv, 1893, Erganzungsheft, p. 279; Landois, ibid., 1908, p. 221; and Stockmann, "Ueber Gummiknoten in Herzfleische bei Erwachsenen," Wiesbaden, 1904.

[2] Warthin: Trans. Assoc. Am. Phys., 1910.

[3] Bruhns: Berlin. klin. Woch., xlii, No. 8.

[4] Wiesner: Centralbl. f. Path. u. path. Anat., 1905, p. 822.

[5] Klotz: Jour. Path. and Bact., 1907, p. 11.

[6] Reuter: Münch. med. Woch., 1906, p. 778; Ztsch. f. Hyg. u. Infektionskh. 1906, p. 49. Benda: Berlin. klin. Woch., 1906, p. 989. Schmorl: Münch. med. Woch., 1907, p. 188. Wright: Boston Med. and Surg. Jour., 1909, p. 539.
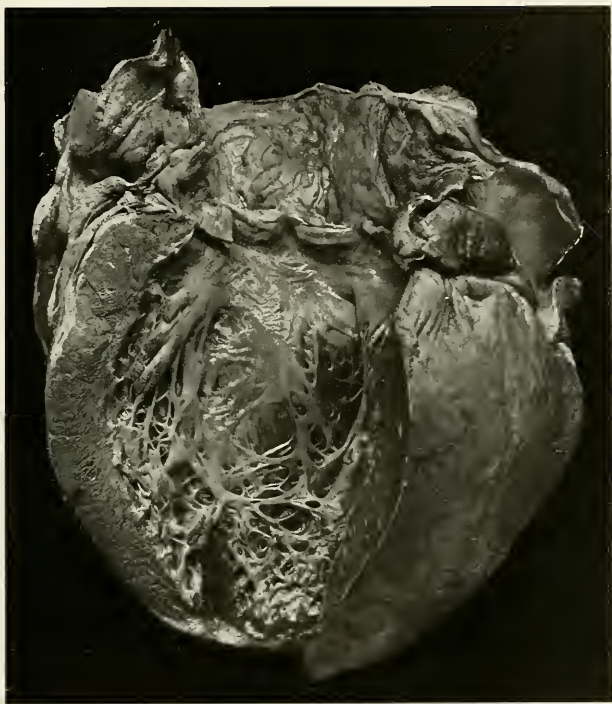
FIG. 72.—SYPHILITIC AORTITIS.

In this specimen the syphilitic process has extended downward along the aortic wall and involved the coronary orifices and the aortic leaflets. The smooth, more or less sharply circumscribed rubbery appearance of the lesions is shown. Also the absence of calcification. (Compare with Figs. 41, 66, and 71. See also under "Cardiac Syphilis," p. 200, and "Diseases of the Aortic Orifice," p. 50.)

leaflets suggested that "the agent which produced the chronic inflammatory and proliferative changes in the wall of the aorta had some part in the disease of the aortic valves."

Of these 21 cases all but 3 had shown the clinical evidences of aortic leakage. There were 55 other cases of aortic endocarditis among the 930 autopsies in which the etiologic factor was an antecedent acute endocarditis (history of infections and involvement of other valves, 21 cases), and others in which the sclerosis was general, involved the whole aorta, and was associated with marked calcification (endarteritis deformans—pure aortic endocarditis, 34 cases).[1]

[1] Longcope: "The Association of Aortic Insufficiency with Syphilis," Jour. Am. Med. Assoc., Jan. 8, 1910.

Aortic cusp
cut away

Auriculo-
ventricular
bundle
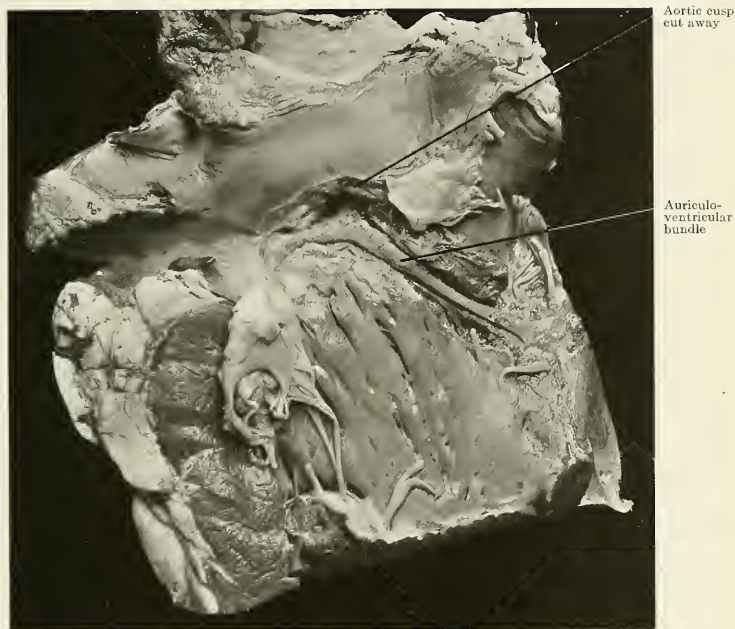
FIG. 73.—THIS SPECIMEN SHOWS A DISSECTION OF THE AURICULO-VENTRICULAR BUNDLE
(BUNDLE OF HIS) IN THE HEART OF A BULLOCK.

The bundle is about 5 mm. in diameter and can be seen grayer than the rest of the mus-
culature, running directly up the middle of the specimen in the left ventricle until it disappears
beneath the heart muscle. In the right ventricle it runs obliquely upward toward the left,
disappearing beneath the auriculo-ventricular valve. (Dissection by Dr. Krumbhaar.) *The
superficial position of the bundle and its proximity to the aortic and mitral valves indicate how
readily this structure might suffer damage in case of an inflammatory or degenerative process in-
volving either of these valves or the intervening endocardium.*

XIII. CONGENITAL LESIONS

IMPERFORATE VENTRICULAR SEPTUM

An imperforate interventricular septum, like other congenital abnormalities, is a condition which may be associated with other developmental malformations—harelip, cleft palate, polydactylism, supernumerary auricles, nipples, etc. It is the commonest of all congenital heart lesions. It is generally associated with other defects, such as obstruction of the pulmonary or tricuspid orifices. The perforation usually occurs in the undefended space, just beneath the aortic valves. As a result of it hypertrophy, and especially dilatation of the right heart, occur if the child lives long enough. Among the Philadelphia Hospital autopsies the following

FIG. 74.—PATULOUS INTERVENTRICULAR SEPTUM.

C. R., male, white. Italian boy. (Pennsylvania Hospital Autopsy 1111. Spec. No. 453. Physician: Dr. M. J. Lewis. Pathologist: Dr. Krumbhaar.)

CLINICAL NOTES: Patient admitted unconscious, with left-sided paralysis. Has never had any acute illness previously. Was a "blue baby," and had always remained cyanotic. He did not play actively. Fingers and toes are clubbed. For three days he had had fever, headache, convulsions, abdominal pain. A loud systolic murmur was heard over the heart.

PATHOLOGIC DIAGNOSIS: *Congenital malformation of the heart. Stenosis of the conus arteriosus. Hypoplasia of the pulmonary artery. Patulous interventricular septum. Acute endocarditis.* Softening of the right cerebral hemisphere.

HEART: Weighs 250 gm. Pericardium: negative. The heart is enlarged, especially to the right side. The ductus arteriosus is easily found and measures 9 cm. in length, 2 cm. in diameter. It does not admit a probe. On opening the heart: *at the junction of the interauricular and interventricular septa there is a large opening between the right and left sides (undefended space); it is about 9 cm. in diameter, easily admitting an ordinary lead-pencil. Its walls are smooth and lined with endocardium. It is evidently congenital.* Foramen ovale closed. Right ventricle 8 mm. Pulmonary artery and the conus arteriosus poorly developed and stenotic. A few millimeters below the base of the valve there are some fine granular vegetations. The left ventricle 12 mm. The heart muscle is deep red, normal in color. The tricuspid valve measures 7 cm. in circumference, the mitral 6 cm., the aorta 3.1 cm. The pulmonary and aortic rings were not measured, in order to preserve the specimen. The coronaries are normal.

MICROSCOPIC EXAMINATION: The muscle-fibers are swollen and everywhere the striations are poorly marked or absent, the fibers having a homogeneous appearance. The nuclei are for the most part normal, though occasionally very large ones are found. The papillary muscles on cross-section show vacuolization of many fibers. Interstitial tissue is increased in a few places. The endocardium is normal except for a slight thickening on the internal surface of the papillary muscle.
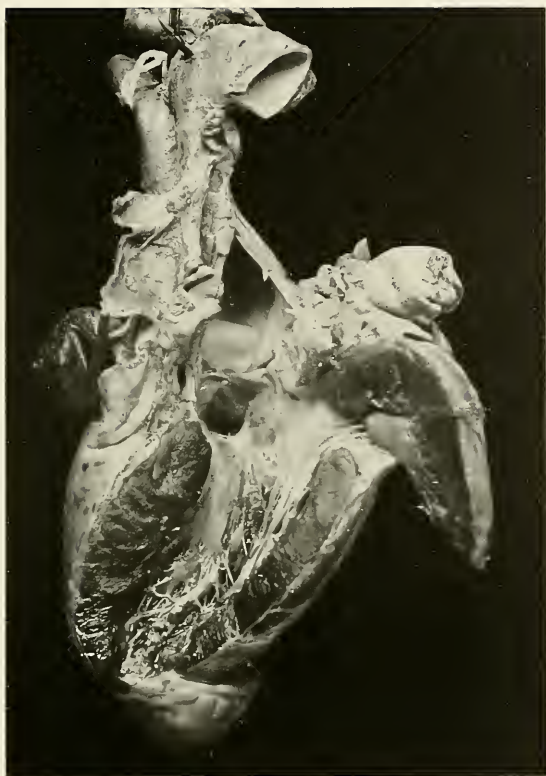
Fig. 74.

lesions of the interventricular septum were found: aneurism, 1; ulceration, 1; rupture, 1; perforation, 2. (See Figs. 74, 76, 77.)

The "observations by His and others have not confirmed Rokitansky's view of this extension upward of the interventricular septum to form the aortic wall, but show that the aortic septum is prolonged downward to assist in closing the interventricular septum at the undefended space. Moreover, independent defects of the interventricular septum, sometimes of large size and evi- dently not of inflammatory origin, and unassociated with any deviation to the right of the aorta, may and do occur. Such conditions cannot be explained on Rokitansky's theory as a deviation of the septa, and must be acknowledged to be a primary arrest of growth of unknown origin." (Abbott.) The effect of an imperforate ventricular septum upon the circulation and upon the rest of the heart depends upon whether it occurs as an isolated lesion or not. In 78 per cent. of Abbott's cases it appeared in combination with other defects; most commonly with pulmonary stenosis. When it occurs alone, it produces hypertrophy of both ventricles, the degree of which is dependent upon the size of the perforation. "As the right ventricle hypertrophies and pressure in the right ventricle increases, the leakage diminishes, so that the effect of the lesion tends to correct itself; on the other hand, the pressure in the pulmonary artery increases. But since the ordinary resistance in the pulmonary circulation is much less than in the systemic, when the forces of both ventricles approximate one another the effect on the pulmonary circulation is the same as though the left ventricle became weaker and the right remained unchanged. Pulmonary engorgements may, therefore, result, with consequent dyspnea. In most cases, however, the hyper- trophy does not reach this point, and it is only when the heart is stimulated by effort or exercise that pulmonary engorgement sets in." (Hirschfelder.)

FIG. 75.—PATENT DUCTUS ARTERIOSUS.

Male infant, thirty-four days old. (Physician: Dr. G. M. Boyd. Pathologist: Dr. A. G. Ellis.[1])

CLINICAL NOTES: At birth the baby was cyanotic and weighed 7 pounds. Respiratory difficulty was present at all times, and the cyanosis was marked during the first few days. Later the blueness became less prominent, especially during short periods in which it almost disappeared. Death occurred during an attack of dyspnea associated with cyanosis.

PATHOLOGIC DIAGNOSIS: *Transposition of the aorta and the pulmonary artery; patent ductus arteriosus; hypertrophy of the right ventricle.* Patent foramen ovale; partial atelectasis of the right lung; general visceral congestion.

PATHOLOGIC NOTES: The heart is essentially normal in size. The wall of the right and left ventricles are respectively 5 and 7 mm. in thickness. Neither the pulmonary artery nor the aorta shows any evidence of stenosis. The foramen ovale is patulous in the form of a slit-like opening 0.5 cm. in length, and the ductus arteriosus allows with ease the passage of a probe 2 mm. in diameter. Neither the ventricles nor the auricles are transposed, and the veins of the latter are normally placed. (Specimen from the Philadelphia Hospital.)

[1] Case reported by Dr. A. G. Ellis: Am. Jour. Obstet., 1905, lii, No. 6.

14

Fig. 76.—Patulous Interventricular Septum with Acute Endocarditis.

(Pennsylvania Hospital. Physician: Dr. H. M. Fisher. Pathologist: Dr. G. C. Robinson.)

Clinical Notes: Patient had dyspnea and cough after exertion, but was otherwise fairly healthy. Heart: hypertrophied, loud systolic murmur at the apex, transmitted to the back. Also a diastolic murmur, loudest over the aortic area. Two years later the patient died after having suffered from gangrene of the nose, the ear, etc., apparently the result of thrombosis.

Pathologic Notes: Partial autopsy disclosed hydrothorax, parenchymatous nephritis, capillary hemorrhages, etc., and the following cardiac condition:

Heart: Is somewhat enlarged; the epicardium is normal, but shows a very small amount of fat. Tricuspid valve (after hardening) measures 10.5 cm. The wall of the right ventricle measures 8 to 10 mm.; its cavity about normal. Tricuspid valve and the chordæ tendineæ of its posterior leaflet show a few fresh vegetations. *In the septum ventriculorum, just to the left of the beginning of the conus arteriosus, there is an oval opening, 3.5 x 2.5 cm. in diameter, which appears as a funnel-shaped excavation in the ventricular septum. The opening into the left ventricle is nearly closed by large wart-like vegetations. These vegetations extend from the opening upward into the conus arteriosus and are continuous with those on the right anterior leaflet of the pulmonary valve.* The conus arteriosus is quite narrowed. Its origin, which is but 4.5 cm. in circumference, is surrounded by a row of delicate vegetations. The pulmonary artery at the base of the valves measures 7 cm. in circumference. All of its leaflets show a considerable thickening and puckering and are the seats of extensive fresh vegetations. The right anterior and posterior leaflets show round knob-like masses measuring 2 to 5 mm. in diameter, hanging to their free margins, while the left anterior pulmonary leaflet is about half covered by large, rather regular vegetations extending all the way across its free margin. There is a small group of warty vegetations extending 1.5 cm. below this leaflet in the conus arteriosus, and within the sinus of Valsalva above it there is a small nodular vegetation, 6 mm. in diameter, attached to the wall of the pulmonary artery. Upon examining the left side of the heart the auricle is found to be normal in proportions. *The mitral valve is somewhat thickened toward its base, but is free from vegetations. The wall of the left ventricle is but slightly thickened (14 mm.). Directly beneath the posterior leaflet of the aortic valve there is an opening in the septum ventriculorum continuous with that seen in the right ventricle. On the left side the opening measures 2.5 x 1.5 cm. It is almost closed, however, by the extensive vegetations springing from its margins. The endocardium of the left ventricle extends into the opening and is apparently continuous with that of the right ventricle.* The direction of the passage between the ventricles is downward and backward from the left to the right side. The aortic ring measures 6 cm. in circumference. All of the aortic valves are much thickened and somewhat contracted. On the anterior and right posterior leaflets there are small verrucose vegetations; *on the left posterior leaflet there is an enormous, irregularly round, nodular vegetation measuring 2.5 x 2.3 x 1.8 cm. in diameter. The vegetation is attached to the entire ventricular aspect of the leaflet, and extends downward into the opening in the septum ventriculorum, nearly closing the same.* No bacteriologic examination was made.
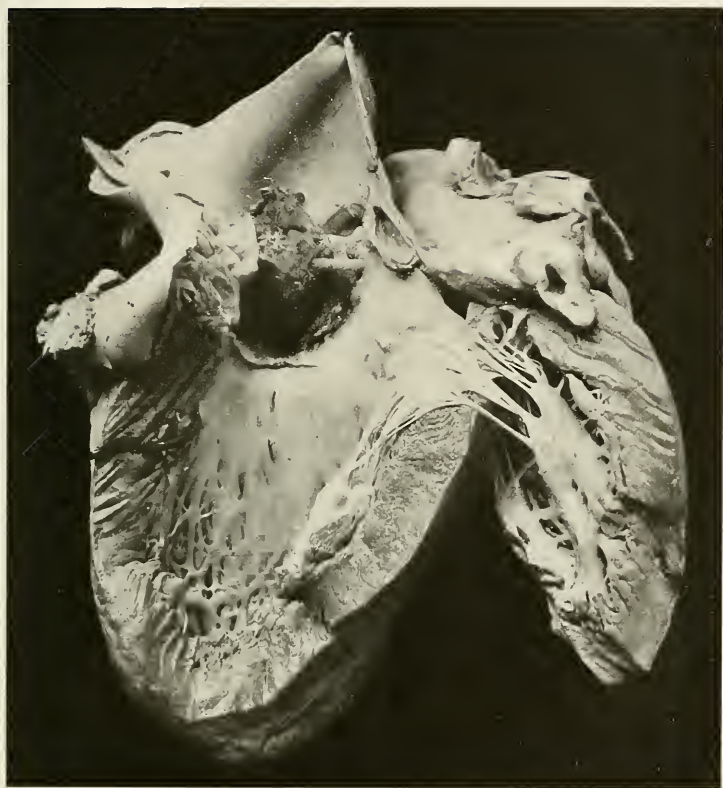
Fig. 76.

TRANSPOSITION OF THE GREAT VESSELS

Transposition of the great vessels is generally associated with a transposition of the other viscera. It is ascribed to non-rotation of the aortic septum from which these vessels are formed, and it is often accompanied by patency of the foramen ovale, interventricular septum, or ductus arteriosus.

"In typical cases the aorta is in front and to the right, the pulmonary artery behind and to the left. At one stage in the normal process both vessels are connected with the right ventricle, the change of the aorta to the left being largely accomplished by the completion of the interventricular septum. Irregularities in the formation of this septum, especially its deviation to the right or left, may result in both vessels arising from one or other of the ventricles, more often the right, an anomaly not exceedingly rare. Transposition of the vessels may be accompanied by transposition of the auricles and veins, or of the ventricles, or both. The transposed vessels may be normal, but usually are not."[1]

As to the frequency of the condition, Theremin found 21 cases among 106 cardiac anomalies at the Foundling Hospital in St. Petersburg, and Vierordt, 76 among 383.

PATULOUS DUCTUS ARTERIOSUS

In an excellent and comprehensive article Goodman[2] has recently summarized what is at present known regarding patency of the ductus arteriosus. Altogether he was able to collect 71 cases, 34 of which were autopsied. A great many different explanations have been offered as to the *modus operandi* by which the ductus Botalli is normally obliterated during the first four weeks of life, and an equal number of hypotheses offered as to the cause of its continued or renewed patency. Among the former the following may be mentioned: Pressure equilibrium between the aorta and pulmonary artery, also contraction of the walls of the duct after the first inspiration; changes in the position of the heart after the last-named act; redundant valve-like intimal folds at the aortic orifice, etc.

Persistent patulosity may occur:

1. As an isolated lesion.
2. In association with other cardiac malformations.

[1] Abbott: Osler's Modern Medicine, vol. iv, p. 370.
[2] E. H. Goodman: Univ. of Penna. Med. Bull., Dec., 1910, p. 509. (Complete bibliography.)

Fig. 77.—Patulous Interventricular Septum with Acute Endocarditis.

The interventricular septum is patulous, but this opening is almost entirely closed by a large mass of recent vegetations which are attached to its margins. (Photograph by Dr. A. R. Allen.)

3. In association with other non-cardiac developmental defects.

The form of the ductus arteriosus may be as follows (Gerhardt):

1. Extreme shortening of the canal, the great vessels being practically united by a simple opening between them.

2. A funnel-shaped opening, with the larger opening on the aortic end. (Relatively common.)

3. A cylindrical shape. (Commonest variety.)

4. Aneurismal dilatation.

Patency of the ductus Botalli, both as an isolated lesion and in combination with other defects, is one of the commoner congenital abnormalities. (See Figs. 75, 83, 84.)

PATULOUS FORAMEN OVALE

Occurrence.—A patulous foramen ovale is a relatively common autopsy finding (Vierordt, 28 per cent.; Zahn, 22.3 per cent.), but mere patency is not necessarily of pathologic importance. The fact that the channel runs obliquely through the auricular septum, and that, therefore, the openings on the two sides are not directly opposite to each other, favors competency, for as soon as intra-auricular pressure on the two sides of the membranes rises, the lateral walls of the channel are pressed together, and tend to close. Under normal circumstances obliteration of the opening is said to result from mechanical irritation, as the result of which the endothelial covering of the two surfaces becomes abraded and adhesion follows. The above-mentioned figures apparently include all grades of patency. An opening large enough to admit the small finger occurred only 9 times in 462 autopsies (1.9 per cent.).[1] At the Philadelphia Hospital there were only recorded 86 cases among 8,640 autopsies (0.9 per cent.).

"The foramen ovale lies in almost a horizontal plane, and not vertically and facing the left." Neither the right- nor the left-sided posture after birth is, therefore, of any consequence in favoring its closure in the newly born infant (Fetterolf and Gittings).[2]

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[1] Hintze and Ogle: quoted Hirschfelder, "Diseases of the Heart and Aorta," 1910, p. 466.

[2] Fetterolf and Gittings: Am. Jour. Children's Dis., Jan., 1910, No. 1.
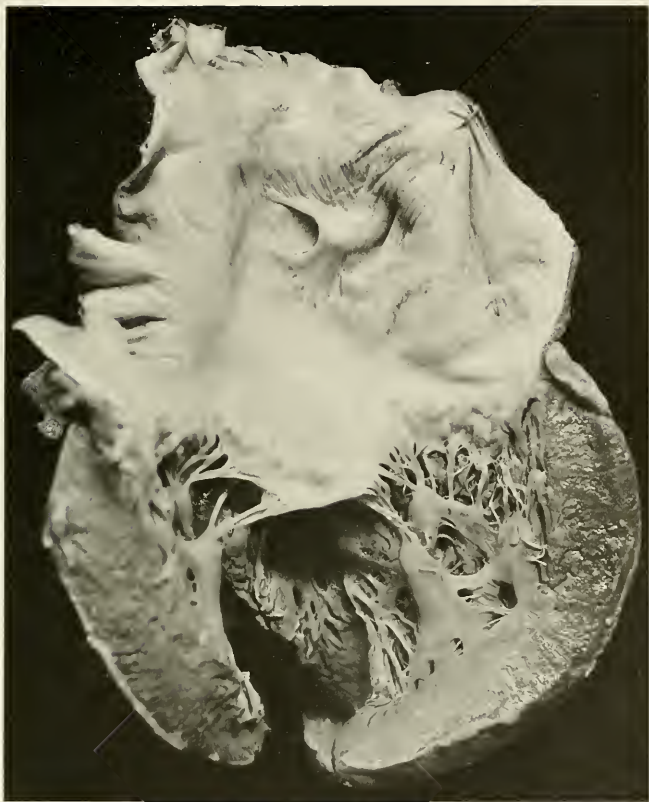
FIG. 78.—PATULOUS FORAMEN OVALE.

Heart of a woman aged seventy years, who died of croupous pneumonia, having advanced general arteriosclerosis. The illustration shows a chronic, more or less diffuse, mitral thickening, with contraction of the chordæ tendineæ, and marked hypertrophy of the left ventricle. The foramen ovale is quite large and patulous, but owing to its oblique course it was probably functionally competent.

Pathologic Physiology.—As has already been intimated, mere patulousness of the foramen ovale need be of but little consequence unless the opening be a very large and direct one. (See Figs. 78, 79, 80.) With valvular disease of the heart, especially in mitral lesions with failing compensation, the defect may become important. Thus, for instance, when the left auricle is over-burdened and dilated, and its internal pressure increased, considerable quantities of blood may regurgitate into the right auricle. Up to a certain point such reflux may be conservative, after the manner of the safety-valve. When the failure of the right heart is superadded, however, a patulous foramen ovale becomes doubly disadvantageous by preventing proper aëration of the blood, and by directly mixing the venous with the arterial currents. Griffiths suggests that slight patency of the foramen may be of actual benefit in case of obstruction in the pulmonary circulation, such as emphysema, since it is less harmful to have some venous blood admitted to the arteries, than to have the individual waterlogged from back-pressure in the right heart. Emboli from the right heart may reach the general circulation by passing through a patulous foramen ovale or interventricular septum or ductus arteriosus.

ABNORMAL FIBROUS BANDS

The so-called abnormal fibrous bands of the heart are chiefly found in the ventricles. According to Tawara, they represent a congenital anomaly of the auriculo-ventricular bundle; an opinion based solely on their course and distribution. Roessle[1] showed that these fibrous bands contained muscular tissue, but regarded their structure as the result of pressure atrophy. Magnus-Alsleben[2] examined ten cases and found muscle-cells often similar in microscopic appearance to the auriculo-ventricular bundle. He suggests that, inasmuch as these bands are of no such great rarity, both the hitherto employed terms "abnormale" and "sehnenfäden" are inappropriate. (See Fig. 82.)

[1] Roessle: Arch. f. klin. Med., 1902, p. 224.
[2] Magnus-Alsleben: Centralb. f. Path. u. path. Anat., 1906, p. 897.

Fig. 79.—Patulous but Competent Foramen Ovale. (University of Pennsylvania Museum.)

Fig. 80.—Patulous but Incompetent Foramen Ovale. (Pennsylvania Hospital, No. 175.)

ANOMALIES OF THE SEMILUNAR VALVES

These anomalies may occur in otherwise normal hearts and have little clinical significance, or they may be associated with coarction of the aorta. Theremin has reported an instance in which both the aortic and pulmonic valves were bicuspid. There has been considerable discussion as to whether the condition was most frequently the result of faulty development or of antenatal endocarditis. Fusion of the leaflets resulting from post-natal infections "is distinguished by the presence behind the fused cusps of a high raphé formed by their united adjacent portions, by the absence of compensatory changes in this and in the fused cusp, and by marked thickening, calcification, and other evidence of inflammatory action" (Abbott).

This anomaly may be attended by no pathologic results, but not infrequently acute endocarditis, arteriosclerotic change, or functional insufficiency as the result of valvular stretching is a sequel of this condition.[1] (See Figs. 81, 82, 83.)

DOUBLE MITRAL[2] OR TRICUSPID[3] ORIFICES

Double orifices have been reported. The abnormal orifice may possess its own papillary muscles and chordæ tendineæ. "Pisenti explained the condition as the result of a congenital fenestration which had transmitted the blood-stream in early embryonic life, and thought that its transformation into a second valvular orifice was an adaptation of growth or compensatory process, the papillary muscles (which develop at the same time as the cusps) growing up with their chordæ tendineæ to its borders." (Abbott.) This hypothesis is tentatively indorsed by the last-named authoress, although rejected by Cohn on the ground that the anomaly does not correspond with what we know regarding any stage of the embryologic process. (See Fig. 85.)

[1] For literature see: Dilg, Virchow's Archiv., 1883, vol. xci; Lannois and Villaret, Bull. et Mem. Soc. Anat., Paris, July, 1905.

[2] Greenfield: Trans. Path. Soc. London, 1876, xxvii, p. 128. Cohn: Inaugural Dissert. Königsberg, 1896. Abbott: Osler's "Modern Medicine," vol. iv, p. 393.

[2] Pisenti: "Di una varissima Anomalia della tricuspide," Peugia, 1888.

FIG. 81.—BICUSPID PULMONARY VALVE. (Specimen from the Mütter Museum of the College of Physicians of Philadelphia.)
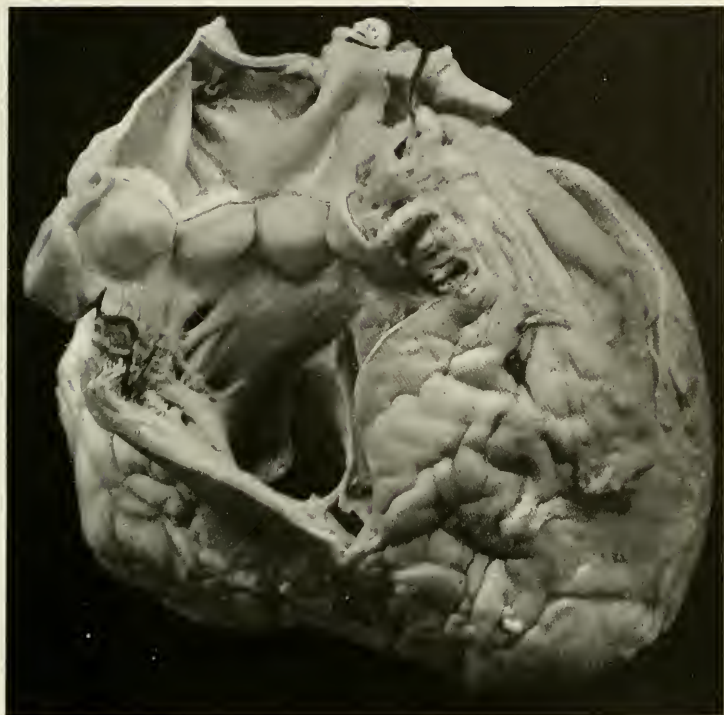
Fig. 82.—Four Pulmonary Valves. (Specimen from the Philadelphia Hospital.)

This anomaly is somewhat more frequent in the pulmonary artery than in the aorta. It usually has no pathologic significance, but congenitally abnormal valves seem to be more frequently subject to subsequent infection.

Fig. 83.—Congenital Atresia of the Aorta, with Patent Ductus Arteriosus.

Male, negro, aged twenty-two years. (W. B.) (Pennsylvania Hospital, 1903. No. 1711. Autopsy 472.)

Clinical History: Pneumonia as a boy; and again 1898. Gonorrhea some years ago. Symptoms: dyspnea, tachycardia, arrhythmia.

Apex-beat in fifth interspace, mid-clavicular line, heart enlarged to the right. First sound booming. No murmurs on admission, but later a soft systolic murmur was heard at the apex from time to time, but not constantly.

Pathologic Diagnosis: *Congenital atresia of the aorta, with patent ductus arteriosus. Bicuspid aortic valve.* Chronic mitral endocarditis. Cardiac hypertrophy, especially of the right side. Thrombosis of the right innominate, internal jugular, axillary, and basilic veins; also of the auricular appendage. Congestion of the viscera, with cardiac hepatic cirrhosis, etc.

Pericardium and Heart, very large, filling the whole anterior mediastinum. Heart extends 8 cm. to right of mid-sternum, at level of fourth costal cartilage. From above down-ward it measures 13 cm.; from the apex diagonally to the base, 20 cm. Pericardium contains 400 c.c. slightly turbid, straw-colored fluid, containing a few flakes of fibrin. The serous sur-faces are smooth and glistening. *Heart weighs 780 gm. It is large and has a peculiar square shape, the apex being very blunt.* The right heart is especially large. The epicardium in some places appears thickened, and is rather opaque and grayish. Subepicardial fat decreased. The vessels are much injected and small punctate hemorrhages are seen, especially at the base. The cavities are all filled with postmortem clots. Both the right auricle and ventricle are large and their walls excessively thickened. The tricuspid orifice measures 12 cm. in circum-ference; its valves are thin and delicate. Pulmonary orifice 9 cm. in circumference. Papillary muscles and columnæ carneæ are exceedingly large and firm. *The actual wall of the right ventricle measures 10 to 17 mm. in thickness,* it being as thick as a moderately hypertrophied left ventricle. Wall of the right auricle 3 to 8 mm. The tip of the auricle is completely filled with a soft, gray, smooth thrombus, the center of which contains a thick, gray, pus-like material. Mitral valves thin and delicate. *The aortic valve shows only two large cusps, but they are thin and delicate.* The aortic orifice is 5.5 cm. in circumference (half the size of the pulmonary); the aorta above it is about the same size. *The cavity of the left ventricle is not very large, but the walls are much hypertrophied, averaging 18 to 20 mm. in thickness. The endocardium is opaque, thick, and white. Muscular bands extend from one side of the wall to the other, forming a coarse network in the cavity.* Coronary arteries are large and patent. A few pinhead-sized, raised points are scattered over the aorta.

Microscopic Diagnosis: *Chronic interstitial myocarditis.* Pericardium shows no especial change. Heart muscle shows degenerative changes in places, while a fibrillated connective tissue containing very few cells fills the areas of degeneration and extends between the muscle-fibers, the latter being large and granular. Endocardium is thickened; connective tissue ex-tends from it to the muscle. (Aorta shown in Fig. 84.)
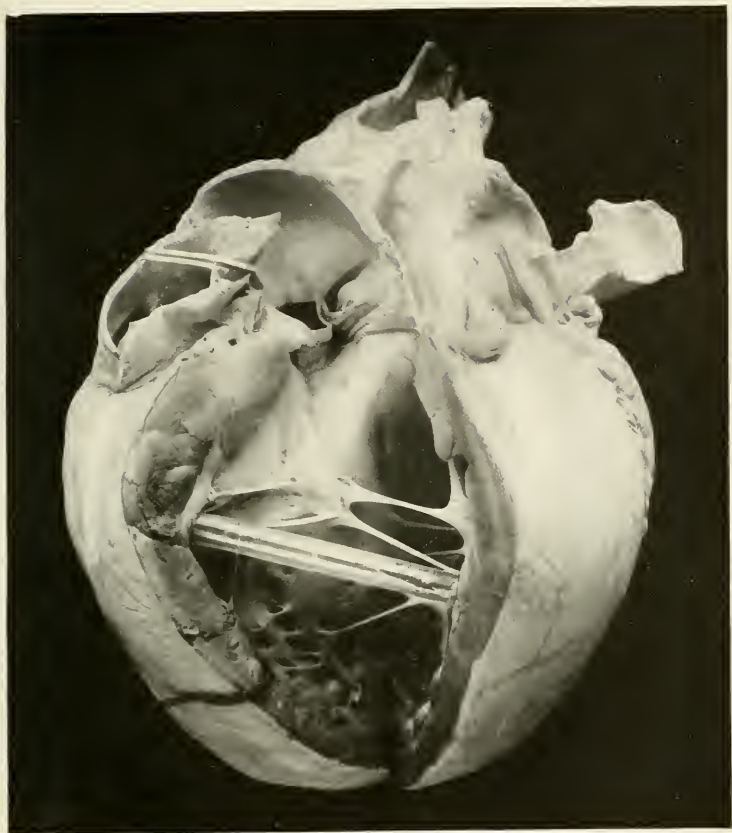
FIG. 83.—BICUSPID AORTIC VALVE.

This specimen also shows marked left ventricular hypertrophy and "abnormal fibrous bands" traversing this chamber. (See p. 222.)

Innominate artery.

Ascending aorta

Pulmonary artery

Left common carotid artery

Left subclavian artery

Ductus arteriosus

Descending aorta
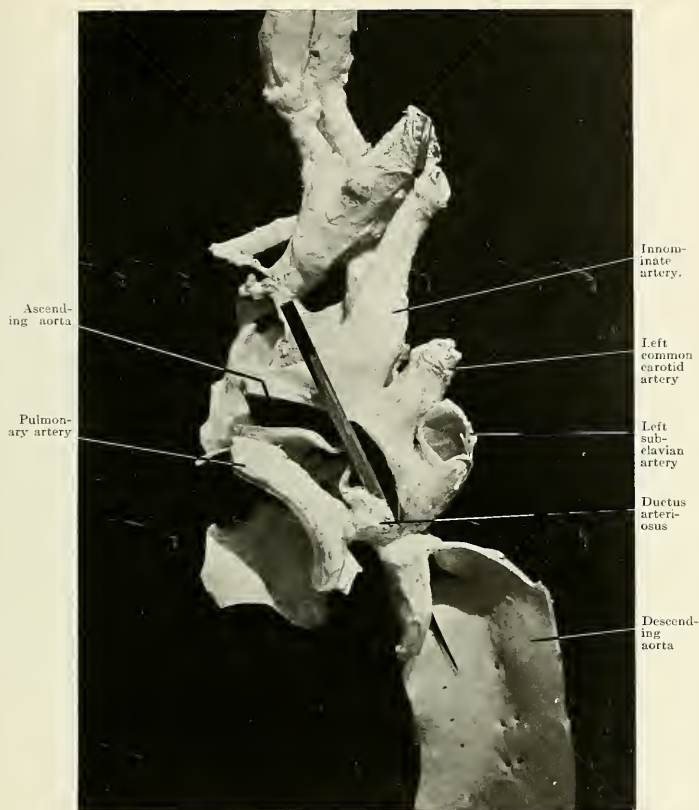
FIG. 84.—CONGENITAL AORTIC STENOSIS WITH PATENCY OF THE DUCTUS ARTERIOSUS.

PATHOLOGIC NOTES: The aorta is very small, measuring at the arch only 4.5 cm. in diameter, while the pulmonary artery is twice this size. The innominate, left vertebral, and subclavian arteries are normal in position and size. *Immediately at the junction of the lower edge of the left subclavian artery and the aorta, the latter vessel shows a sudden and marked constriction, the external diameter of which measures 12 mm., while 3 cm. above and below the constriction the aorta measures 2 and 2.5 cm. in diameter.* On opening the aorta and looking down toward the constriction the vessel appears to end in a smooth, rounded, blind pouch, but on closer inspection a pinhead-sized opening can be seen, through which a small probe can be passed. Connecting the pulmonary artery just where it branches, and the aorta just at the proximal side of the constriction, is a narrow vessel, about 8 mm. in length and 5 mm. in diameter, through which a probe can be passed. The aorta throughout its length is narrow, but its branches are about normal in size. (Pennsylvania Hospital, No. 317. *These are the vessels belonging to the heart shown in Fig. 83.*)

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FIG. 85.—DOUBLE MITRAL ORIFICE.

C. D., male, aged twenty-two years.   (Pennsylvania Hospital 235.   349.)

CLINICAL NOTES: Patient died of typhoid fever, complicated by bronchopneumonia and erysipelas.   He had had no circulatory symptoms at any time before, nor physical signs in dicative of cardiac disease.

PATHOLOGIC NOTES: Heart weighs 290 gm. The cavities are normal in proportion, except the left auricle, which is dilated.   All of the valves are normal except the *mitral, which shows thickening.   The chordæ tendineæ are thickened, white, and fibrous.   The papillary muscles are large and thick; and beneath their posterior segment the three portions are distinct as three separate muscles.   The chordæ tendineæ reach from two of them to the anterior leaflet, which is large, measuring 3 cm. from the annulus fibrosum to the free edge in a straight line.   The papillary muscle, which is normally attached to the edge of the valve, attaches here almost at the central portion of the leaflet.   The valve is perforated by an opening 1 cm. in diameter, the chordæ tendineæ at taching about the margin of this opening.   There are thus two auriculo-ventricular openings, sur rounded by chordæ tendineæ, with normal margins.   The entire ventriculo-ventricular ring measures 9.5 cm. in circumference.*   The heart muscle is dark reddish-brown and firm.   Left ventricle: 18 to 20 mm.   Coronaries patent.   Foramen ovale closed.   Auricular appendages free from thrombi.   Aorta smooth.

Microscopically: Slight edema of the heart muscle with pigmentation of the muscle-fibers, but no other changes.

(The match-stick passes through the accessory auriculo-ventricular orifice.)
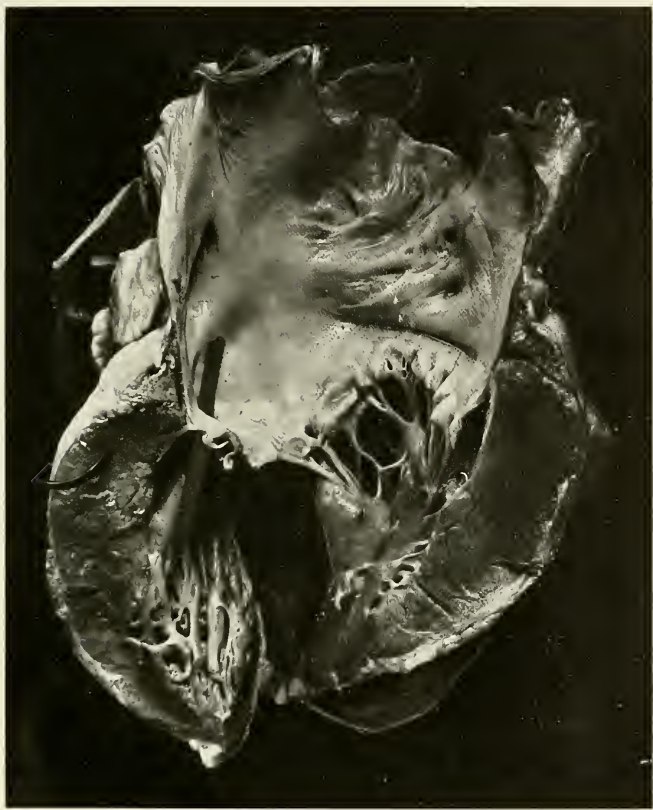
FIG. 85.

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